# ACTA RADIOLOGICA

FOUNDED IN 1921 BY GOSTA FORSSELL

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN



## DIAGNOSIS

## INDICES to Vol 10 (1970)

January March May July September November

# Contents of Volume 10 — DIAGNOSIS

ACTA RADIOLOGICA

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Vol 10 Fasc 1 — DIAGNOSIS — 1970 January

# NORMAL SIZE OF THE INTERNAL CAROTID, MIDDLE CEREBRAL AND ANTERIOR CEREBRAL ARTERIES

by

TRYGVE O GABRIELSEN and TORGNY GREITZ

The size of the internal carotid, middle cerebral and anterior cerebral arteries have been investigated by WOLLSCHLAEGER & WOLLSCHLAEGER (1966) in unselected cadaver brains as well as with carotid angiography performed during life However, neither the angiographic nor the clinical diagnoses were given for the living subjects

The present investigation has been made in an attempt to determine the normal size of the internal carotid, middle cerebral and anterior cerebral arteries

*Material and Methods* The records of 4 402 carotid angiographies coded as normal during the fifteen year period 1950—1964 were screened in order to find as many normal examinations as possible Of all these examinations, 4 139 had been performed at Serafimerlasarettet and 263, the more recent ones, in the Department of Neuroradiology at Karolinska sjukhuset.

Most of the cases were eliminated from the study either because of the history, or signs pointing to disease of the central nervous system other than epilepsy An abnormal electro-encephalogram among the epilepsy cases was not regarded as a ground for exclusion No case with abnormal neurologic signs or recent

From the Department of Neuroradiology (Director Prof T Greitz), Karolinska Sjukhuset, Stockholm, Sweden. Submitted for publication 5 February 1969

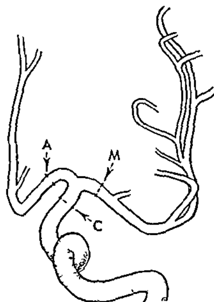



Fig 1

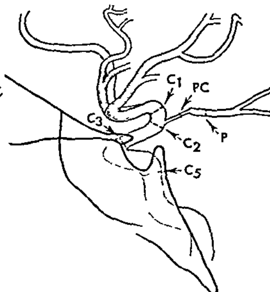



Fig 2

Fig 1 Diameters of the internal carotid, middle cerebral and anterior cerebral arteries, determined in anteroposterior roentgenograms of normal carotid angiographies

Fig 2 Various diameters of the internal carotid artery determined in lateral roentgenograms of normal carotid angiographies

were obtained by serial filming with a 10 by 12 inch Elema Schonander changer at 85 cm film-focus distance The 10 by 12 inch Elema-Schonander cassette holder (LINDGREN 1947) and a film focus distance of 70 cm had been used for the 112 earlier examinations

The measurements were carried out as follows The diameter of the contrast-filled lumen was marked with a sharp lead pencil and the diameter measured with a transparent ruler to an attempted accuracy of one tenth of a millimeter. In order to determine the standard error of measurement, both writers in 50 of the 156 examinations, made two sets of measurements, all four sets independent of each other

Measurements C, M and A were taken both from anteroposterior and half-axial views, in which the petrous ridge was projected below or above the roof of the orbit, C was the diameter of the internal carotid artery 5 mm proximal to its bifurcation into the anterior and middle cerebral arteries The size of the middle cerebral artery (M) and, respectively, the anterior cerebral artery (A) were measured 5 mm beyond their origin (Fig 1) Measurements of the arterial

history of head injury or subarachnoid hemorrhage was included A history of trigeminal neuralgia, migraine, and other types of headache, was considered acceptable There were no clinical notes to suggest that angiography had ever been carried out during an acute attack of migraine

If additional roentgenographic investigation or subsequent evidence revealed even probable central nervous system disease other than as specified above, such a case was excluded from the study, cases of relatively minor deformity or asymmetry of the skull were thus eliminated Exclusion of angiographies performed under general anesthesia explains the absence of children in the series Examinations with perivascular or subintimal injection of contrast medium were discarded

Only studies of good technical quality, with at least one lateral and one frontal roentgenogram in the arterial phase, were included Arterial measurements were often made from both anteroposterior and half-axial projections from the same carotid angiography Cases of even minimal atherosclerosis involving the cerebral arteries, and those having known cerebral atrophy of either central or cortical type, were eliminated from the investigation

One hundred and thirty-three cases, which passed all requirements for 'normality', also had normal encephalographies In the remaining cases without pneumograms, the carotid angiographies were used for measurement only when careful scrutiny of the venous phase pointed to a normal size of the lateral ventricles

These strict criteria permitted measurement of the arterial size to be performed in 156 angiographies from 72 males and 84 females, ranging in age from 13 to 69 years

| Number of | 0—9 | 10—19 | 20—29 | 30—39 | 40—49 | 50—59 | 60—69 years |
|---|---|---|---|---|---|---|---|
| examinations | 0 | 20 | 42 | 51 | 25 | 14 | 4 |

The clinical diagnoses in these cases are listed below according to frequency

| | Cases |
|---|---|
| Epilepsy | 120 |
| Trigeminal neuralgia | 4 |
| Migraine | 10 |
| Other types of headache | 22 |

Although bilateral examinations were performed in some of the cases, only one examination (either right or left) per case was included in the study All examinations hade been carried out by direct percutaneous puncture of either the common carotid or the internal carotid arteries The latest 44 angiographies

**Table 1**

*Mean values for various diameters of normal cerebral arteries based on 156 normal carotid angiographies and no correction for sex and skull size*

| Measurement | Mean diameter | Standard deviation |
|---|---|---|
| M | 3.82 mm | 0.43 mm |
| A | 3.02 mm | 0.50 mm |
| C | 4.57 mm | 0.46 mm |
| $C_1$ | 3.78 mm | 0.43 mm |
| $C_2$ | 4.08 mm | 0.47 mm |
| $C_3$ | 5.12 mm | 0.63 mm |
| $C_4$ | 5.80 mm | 0.76 mm |
| $C_5$ | 5.90 mm | 0.73 mm |
| Siphon length | 15.1 mm | 2.45 mm |

**Table 2**

*Influence of sex and external biparietal diameter (W measured in cm) on the size of the internal carotid and middle cerebral arteries expressed in mm*

| Measurement | Male | Female |
|---|---|---|
| M | 1.97+0.118 W | 1.78+0.118 W |
| C | 2.99+0.100 W | 2.81+0.100 W |
| $C_2$ | 4.56+0.112 W | 3.91+0.112 W |
| $M+C+C_2$ | 9.52+0.330 W | 8.50+0.330 W |

by performing measurements on test films that have also been measured by the observer whose data were used in this study.

The mean values obtained for the various arterial diameters in the total material, with no corrections made for sex and skull size, are presented in Table 1. The measurements for the posterior cerebral and posterior communicating arteries could be made in so few angiographies that the results of these were not included. Measurement $C_6$ could be performed in only 105 cases. The value for $C_6$ was practically the same in cases subjected to internal carotid artery puncture and in those subjected to puncture of the common carotid artery.

The statistical analysis ($C_6$ not included) revealed no significant correlation between the measured size of the cerebral arteries and the following variables: site of injection (internal against common carotid artery), side of injection, electroencephalographic findings, blood pressure, and age.

diameters were made on the lateral roentgenograms (Fig 2) at the following locations the internal carotid artery 5 mm peripheral to its junction with the posterior communicating artery ($C_1$), the internal carotid artery just proximal to the junction with the posterior communicating artery ($C_2$), the internal carotid artery at the level of the tuberculum sellae ($C_3$), the internal carotid artery just proximal to its bend at the posterior aspect of the cavernosus sinus ($C_5$), the internal carotid artery at the level of the atlas ($C_F$), the posterior communicating artery 5 mm posterior to its connection with the internal carotid artery (PC), and the posterior cerebral artery 5 mm peripheral to its junction with the posterior communicating artery (P) Measurement $C_1$ occasionally had to be made less than 5 mm peripheral to the posterior communicating artery when this part of the internal carotid artery was unusually short The length of the carotid siphon from the tuberculum sellae was also measured

The data were studied statistically in a series of multiple regression analyses performed with an automatic computer The initial analysis was carried but by considering the sum of three measurements ($M + C + C_5$) as one dependent variable in order to make a preliminary exploration and to decrease the adverse effect of measurement errors Investigation was made of the manner in which this dependent variable was affected by the simultaneous variation of background variables, such as age and sex, clinical diagnosis, EEG findings, systolic and diastolic blood pressure, skull width and skull length, internal or external carotid injection, injection on left or right side, serial or no serial filming, and the projections used In this analysis the dependent variable ($M + C + C_5$) was studied in relation to each background independent variable in order to judge the amount of dependence when other independent variables were held constant In the next stage, the relationships of all single artery measurements (A, M, C, $C_1$, $C_2$ etc) to those variables that seemed important in the initial exploration were investigated

## Results

The measurements analysed by multiple regression were all performed by the same observer, whose standard error of measurement relating to a single determination was estimated to be 0 127 mm for C, 0 124 mm for M, 0 146 mm for $C_1$ and 0 122 mm for $C_5$ These standard errors were somewhat larger for the other observer The figures indicate a very good reproducibility as regards repeat measurements on the same film On the other hand, there is an indication of systematic differences between observers amounting to as much as 0 15 mm Anybody using the figures now given as a standard should be aware of this source of error A possibility of making adjustments for errors of this type exists

**Table 1**

*Mean values for various diameters of normal cerebral arteries based on 156 normal carotid angiographies and no correction for sex and skull size*

| Measurement | Mean diameter | Standard deviation |
|---|---|---|
| M | 3 82 mm | 0 43 mm |
| A | 3 02 mm | 0 50 mm |
| C | 4 57 mm | 0 46 mm |
| $C_1$ | 3 78 mm | 0 43 mm |
| $C_2$ | 4 08 mm | 0 47 mm |
| $C_3$ | 5 12 mm | 0 63 mm |
| $C_5$ | 5 80 mm | 0 76 mm |
| $C_6$ | 5 90 mm | 0 73 mm |
| Siphon length | 15 1 mm | 2 45 mm |

**Table 2**

*Influence of sex and external biparietal diameter (W measured in cm) on the size of the internal carotid and middle cerebral arteries expressed in mm*

| Measurement | Male | Female |
|---|---|---|
| M | 1 97+0 118 W | 1 78+0 118 W |
| C | 2 99+0 100 W | 2 81+0 100 W |
| $C_5$ | 4 56+0 112 W | 3 91+0 112 W |
| $M+C+C_5$ | 9 52+0 330 W | 8 50+0 330 W |

by performing measurements on test films that have also been measured by the observer whose data were used in this study

The mean values obtained for the various arterial diameters in the total material, with no corrections made for sex and skull size, are presented in Table 1 The measurements for the posterior cerebral and posterior communicating arteries could be made in so few angiographies that the results of these were not included Measurement $C_6$ could be performed in only 105 cases. The value for $C_6$ was practically the same in cases subjected to internal carotid artery puncture and in those subjected to puncture of the common carotid artery

The statistical analysis ($C_6$ not included) revealed no significant correlation between the measured size of the cerebral arteries and the following variables site of injection (internal against common carotid artery), side of injection, electroencephalographic findings, blood pressure, and age.

The electroencephalographic findings were analyzed not only as normal against abnormal but also in sub groups as focal versus non-focal and lateralizing versus non-lateralizing Blood pressure data were analyzed separately in terms of systolic and diastolic pressures as well as pulse pressure

Age by itself was not a statistically significant factor, although there was a slight tendency toward increased arterial size with advancing age No statistically significant difference in arterial size could be found between the older angio graphic and the more recent examinations with serial filming Neither was the angle of the central beam for filming in frontal views of any definite statistical significance The trend was for measurements C, M, and to be a little greater in half-axial than in anteroposterior views Arterial size taken as a sum of M, C and $C_5$ was significantly dependent on sex (T value of 5 46) even when the effect of skull size was eliminated by giving this a constant value The finding of cerebral arteries smaller in females than males was reflected more in measurement $C_5$ than C and M, both with regard to the difference (Table 2) and its significance, as demonstrated with T values, of 5 92, 2 38 and 2 65, respectively

Arterial size (sum of M, C, and $C_5$) was not significantly related to maximum skull length from the inner table of the frontal bone to the inner table of the occipital bone when the maximum external cranial width in the parietal area was kept constant This latter measurement, however, showed a correlation with increasing size of the cerebral arteries (T value of 2 72) when the skull length was held constant The external biparietal diameter was also individually correlated in a positive manner with measurements $C_5$ (T value of 1 58), C (T value of 1 90), and M (T value of 2 36)

The combined effect of sex and skull width on M, $C_1$, $C_5$, and the sum of these variables, are indicated by the formulas in Table 3 where $W$ is the external biparietal diameter measured in centimeters

Cases with a history of migraine had smaller arteries (T value of 4 05 for the sum of M, C, and $C_5$) than the total group Although nine of ten cases with migraine were females, the correlation between migraine and small arterial size could not be accounted for entirely on the basis of sex and skull size A less striking, opposite relationship was noted for the other types of headache and trigeminal neuralgia, in which the arterial size statistically was larger than for either the entire material of 156 cases or the epilepsy group (T value of 2 56)

When M, C, and $C_5$ were studied individually, C and M bore a less marked relationship to the clinical history of migraine, other headache, and trigeminal neuralgia, in that order of decreasing dependence Compared to the total group, $C_5$ tended to be greater in the four cases of trigeminal neuralgia (T value of + 1 63), greater in other types of headache (T value of + 2 64), and smaller in migraine (T value of — 2 95)

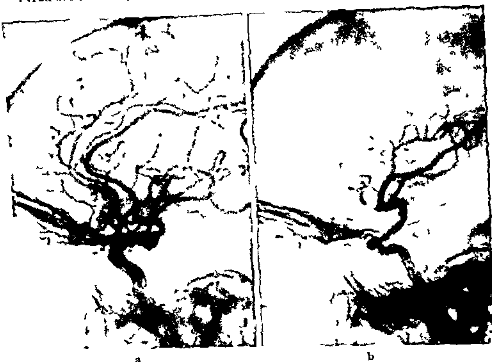



Fig 3 Normal case a) Lateral projection in left carotid angiography The internal carotid artery is unusually wide and supplies both pericallosal arteries b) The right internal carotid artery supplies only the middle cerebral artery and is narrow

Inspection of the data for cases with migraine revealed that eight of the ten had a C size smaller than the expected mean with regard to sex and skull width Three of these eight cases had a $C_5$ of particularly small size

With a *T* value of —2 06 the cases in which encephalography had been performed had slightly smaller cerebral arteries (0 49 *mm* difference for the sum of M, C, and $C_5$) than those without *such* examinations

## Discussion

Radiologic examinations associated with significant discomfort and possibly with morbidity, are rarely performed in *clinically* 'normal cases For this reason, it is difficult to collect a large *series of* carotid angiographies of normal individuals The present *material of* carotid angiographies represents a highly select group both from the *clinical and the radio*logic aspects The mean age was 33 years, which reflects clinical selection Radiologic selection also eliminated

many cases in the older age groups on the basis of even minor cerebral atherosclerosis, ectasia of the cerebral arteries and cerebral atrophy

One might question whether the present results would have been different if carotid angiographies of cases presenting radiologic evidence of ectatic and atherosclerotic cerebral arteries had been included A check investigation of part of the material has been made in order to judge the effects of such selectivity Of 263 carotid angiographies coded as normal in the Department of Neuroradiology, Karolinska sjukhuset, only thirteen met the criteria for 'normal' During the same period, there were 34 carotid angiographies coded as only ectasia and 8 as only atherosclerosis, thirty-four of these forty-two cases would have been excluded on the basis of various neurologic abnormalities and six of the remaining seven cases would have been eliminated due to other abnormal states diagnosed by additional roentgenographic examinations That leaves one case with ectasia as the only objective evidence of clinically and radiologically presumed abnormality It seems probable that there had been proportionately fewer cases diagnosed as ectasia of the cerebral arteries at Serafimerlasarettet

It thus seems unlikely that inclusion of carotid angiographies with ectatic and atherosclerotic arteries would have significantly altered the values that have been cited as normal diameters for the cerebral arteries However, it might have slightly increased the average age of the patients and influenced the correlation of arterial size with age and blood pressure

Although the difference was minor, the cerebral artery size was smaller (a difference of 0 5 mm for the sum of M, C and $C_5$), with statistical significance, in the 133 cases investigated with encephalography than in those without such examinations The selection of cases was probably responsible Cases in which also encephalography was normal may be more 'normal

The writers are well aware of the fact that the contrast media used for carotid angiography produce dilatation of the cerebral veins (GREITZ 1966) and probably also of the arteries (HUBER & HANDA 1967) However, such arterial dilatation apparently develops after maximum filling of the carotid siphon and could not significantly have affected our measurements

Cases with subintimal injection of contrast medium were not included in the study because this procedure often leads to reduced blood flow in the carotid artery and the artery might be narrowed Nor were examinations with intracranial arterial spasm, which had been coded as pathologic, included in the study Cases with marked spasm of the internal carotid artery in the neck had sometimes been coded as normal but were also excluded Some spasm may be associated with every carotid puncture but always stops short of the carotid canal, this can be accurately determined since the walls of the carotid canal are easily seen when the artery is filled

The size of the error of measurement may be appreciable in measurements from an individual examination as compared with the small variations reported as dependent on sex and skull width However, this does not alter the statistical significance of findings based on a large number of examinations. An error of measurement must also be differentiated from the standard deviation cited for each mean arterial measurement The latter is mainly a function of anatomical variation or possibly pathologic change The largest standard deviation was found for measurement A It is well known that the first portion of the anterior cerebral artery may be small on one side and commensurately larger on the other side, it is reasonable to assume that such variation will influence the size of the internal carotid artery (Fig 3) The writers made no systematic investigation of the relationship between the size of the internal carotid artery and variations in the circle of Willis

Spasm of the intracranial arteries has been observed during an acute attack of migraine The writers cannot completely rule out the possibility that the three patients with migraine, who had the narrowest arteries, may have been examined by carotid angiography during at least the initial stage of an acute attack On the other hand, the present findings also raise the possibility that patients with migraine may have had cerebral arteries subnormal in size even between acute attacks

No firm conclusions can be reached regarding trigeminal neuralgia, since there were only four such patients in the present material The trend towards an increase in the $C_5$ measurement in these patients probably warrants further investigation

An increased size in the $C_5$ measurement in the group of other types of headache suggests another etiologic mechanism than for migraine

## Conclusions

The size of the internal carotid and middle cerebral arteries is somewhat dependent on sex and skull width In this study of strictly selected, normal carotid angiographies, no definite correlation of statistical significance between the size of these cerebral arteries and the variables site of injection, side of injection, age of patient, blood pressure, and electro-encephalographic findings was evident As compared to the epilepsy group of the entire material, the internal carotid artery in other types of headache as

A series of test films for calibrating purposes may on request be obtained from Professor T Greitz, Karolinska sjukhuset 104 01 Stockholm 60 Sweden

## Acknowledgements

The statistical analysis was done by Mr Erik Leander, Lecturer in Statistics, University of Stockholm *The study was supported in part by a grant from the Research Council of* the Swedish Life Offices Most of the data for this investigation were collected in 1965 while one of the authors (T O G ) was on an off campus assignment from the Department of Radiology, University of Michigan Medical Center, Ann Arbor, Michigan, U S A



## SUMMARY

The size of the internal carotid, the middle cerebral, and the anterior cerebral arteries was determined in 156 normal carotid angiographies selected by strict clinical and radiologic criteria The data were analyzed statistically

## ZUSAMMENFASSUNG

Die Weite der Aa carotis interna cerebralis media und cerebralis anterior wurde in 156 normalen Karotisangiographien gemessen, die durch klinischen und radiologischen Kriterien ausgewählt wurden Die Daten wurden statistisch analysiert

## RÉSUMÉ

Les auteurs ont mesuré sur 156 angiographies carotidiennes normales, choisies sur des critères cliniques et radiologiques très stricts, le diametre de l'artère carotide interne et des arteres cérébrales moyenne et antérieure Ils ont analysé statistiquement ces résultats en fonction de plusieurs variables


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# SKULL SIZE AND VENTRICULAR DILATATION IN SUBDURAL HYGROMA IN INFANTS

by

S CRONQVIST and H O EFSING

A new index for determination of the size of the neurocranium has recently been applied in a series of cases of various neurologic disorders (CRONQVIST 1968) The skull was found to be enlarged in 15 out of 20 children with subdural hygroma Since in early age the size and the form of the neurocranium is dependent upon the intracranial content, it was at first believed that the hygroma itself, being a space occupying process, was the direct cause of this enlargement We have, however, noted that disproportion almost always existed between the degree of cranial enlargement and the depth and extent of the hygroma, the size of the neurocranium far exceeded its normal upper limit even if the hygroma was only a few millimeters deep This observation called for another explanation as to the cause of the increase in cranial size in these cases and prompted a review of our series of cases examined roentgenologically with the diagnosis of subdural hygroma

*Methods* Cases of probable subdural hygroma at our hospital are always referred for roentgenologic examination This consists of conventional skull films and encephalography, which, in our opinion, is the only special procedure needed for a diagnosis and only exceptionally has to be supplemented with angiography

Submitted for publication 21 March 1969

## Acknowledgements

The statistical analysis was done by Mr Erik Leander Lecturer in Statistics University of Stockholm The study was supported in part by a grant from the Research Council of the Swedish Life Offices Most of the data for this investigation were collected in 1965 while one of the authors (T O G ) was on an off campus assignment from the Department of Radiology University of Michigan Medical Center, Ann Arbor, Michigan U S A

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## Results

Roentgenologic examination of the skull before operation disclosed enlargement of the neurocranium in twenty eight of the thirty nine cases The diagnosis was based upon the cranial index, which in these twenty eight cases proved to exceed the upper normal limit of 56 0 Encephalography or angiography indicated unilateral hygroma in fourteen and bilateral in twenty three cases The roentgenologic diagnosis was uncertain in two cases Ventricular dilatation with an index exceeding 0 30 was present in thirty two of the cases

The ventricles were symmetric, i e there was no significant difference in the sizes of the right and left ventricles, in eighteen cases, with an operation finding of bilateral hygroma in ten and unilateral hygroma in eight cases Asymmetry with a difference between the Evans index on the two sides equal to or exceeding 0 02 was noted in twenty one cases Ten of these had bilateral hygroma at operation a unilateral hygroma being present in the remaining eleven cases The widest ventricle lay on the side of the hygroma in six and on the contralateral side in five of these eleven cases

The relation between the size of the neurocranium and the degree of ventricular dilation was further investigated The Evans index indicated ventricular dilatation in twenty five of the twenty eight cases with an enlarged neurocranium (C index > 56 0) Dilated ventricles were also present in seven of the eleven cases with a normal cranial size (C-index < 56 0)

None of the six postoperative encephalographic studies was undertaken merely to control the result of the operation the indication for the investigation was either persistence of symptoms or development of new neurologic signs Encephalography was completely normal in three cases One case had normal ventricles but no passage of gas over the convexity on the operated side was seen Marked atrophy both central and cortical was noted on the operated side in the fifth case Increased dilatation of the ventricles was present in the sixth case operated upon for unilateral hygroma there were however no signs of any residues of the hygroma the air over the the convexity being in close contact with the internal table of the skull The gas reached the convexity of the brain from the interpeduncular cistern via the dilated ambient cistern with no air passing beyond the chiasmatic cistern i e there were signs of basal arachnoiditis The postoperative skull study indicated an increase in the cranial index as compared to that in the earlier investigation

## Discussion

Increase in the size of the neurocranium measured along the circumference of the skull as a sign of chronic subdural hygroma in children was established by

The size of the neurocranium is determined from these films by means of the cranial index developed by one of the present authors (CRONQVIST 1968). The index is based upon measurements made between the inner tables of the skull and include the greatest length (L), greatest width (W) and greatest height (H). The latter is the maximum perpendicular distance between a line drawn from the nasion to the posterior margin of the foramen magnum and the vault of the skull. In addition, the maximum distance between the inner margins of the two necks of the mandible is measured on the film obtained in a.p. projection (M). The cranial index (C-index) is then obtained from the formula $C = \frac{L + W + H}{M} \times 10$. The mean value of this index based upon normal skull films is 53.5 ± 2 × 1.21. A value above 56.0 thus indicates a pathologic increase in size of the neurocranium.

The encephalographic changes characterizing a subdural hygroma are of two different kinds (ROBERTSON 1957). The hygroma is sometimes manifest because of an increased distance between the calvarium and the surface of the brain, i.e. the gas-filled sulci on the convexity (DYKE 1936). This finding is diagnostic. Sometimes, however, no gas passes to the convexity on the side of the hygroma (LINDGREN 1942), this is suggestive but does not permit of a definite diagnosis.

In this series, the size of the cranial ventricles was determined by the method of EVANS (1942). The maximum width of the anterior horns was taken as the greatest distance from the septum pellucidum to the most lateral border of the ventricle on each side in the a.p. films. In addition, the distance between the midline and the inner table of the skull was measured on both sides. The ventricular measurement and the skull measurement from each side were interrelated. The index thus obtained has, according to EVANS, a normal upper limit of 0.30, an index above this is thus to be considered as pathologic and indicates dilatation of the lateral ventricles. Measurements for the normal variation in the width of the anterior horns have been given by LODIN (1968). We have used these figures for calculating the difference in the Evans' index on the two sides. A value equal to or above 0.02 was found to signify pathologic asymmetry.

*Material.* The present series consists of 39 cases, 27 boys and 12 girls of ages varying between one month and 19 months, with an average of 7 months. Encephalography with adequate air filling of the ventricular system had been made in all cases. Conventional roentgenography of the skull was carried out prior to operation, which verified the presence of hygroma, unilateral or bilateral, in all the thirty-nine cases. Postoperative encephalography was performed in six cases.

hygroma compressing the subarachnoid space, with impairment of the circulation of the spinal fluid and, as a consequence, its resorbtion The other kind seems to be secondary to atrophy of the brain tissue also evident as cortical changes, i e widened sulci (cf CRONQVIST 1968)

Since, as has been shown, ventricular dilatation seems to be reflected in the size of the head it was thought of interest to compare the skull size and the type of encephalographic changes characterized or suggesting the presence of a hygroma It was found that the group with no air passing over the convexity had a larger cranial index than the second group with air-filled sulci The cranial index of the two groups was 58 1 and 56 1, respectively Although there is so far no statistical analysis, this observation would appear to favour the existence of two different types of ventricular dilatation in cases of subdural hygroma

Two different methods of examination should be used for the further analyses of the mechanism of ventricular dilatation One is a new isotope method of gamma cisternography (DICHIRO) which permits studies of the pathways of the cerebrospinal fluid and of its resorbtion There are reasons to believe that the procedure will afford valuable information even from the viewpoint of diagnosis The other examination that should be carried out is postoperative encephalography The aim of such a follow-up study would be to control the results of surgery as to passage of gas in the subarachnoid space or regression of the medial displacement of the surface of the brain registered prior to operation, and ventricular size

The observations on the six postoperative encephalographies available in this series are not conclusive The indications for the investigations were persistent symptoms or development of new neurologic signs Thus, no examination was performed in cases with obvious regression of clinical signs However, even in the present cases no further ventricular dilatation was present after operation, with the exception of one case with added basal arachnoiditis It should be pointed out that results of such an encephalographic follow-up investigation as suggested may help in solving the disputed problems as to whether cases of hygroma should be actively treated or not

## SUMMARY

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enl [illegible] A relationship between the two entities seems to exist Possible explanations and further studies are suggested

INGRAHAM & MATSON (1954), and was present in about 29 per cent of their cases A higher figure was given by FREUNDLICH et coll (1956) who found the circumference of the head to be enlarged in fourteen of nineteen cases These authors pointed out, however, that their cases were selected, most of them being admitted to hospital because of this special sign

The cranial index used in the present study has previously proved to be a sensitive indicator of changes in the size of the skull Enlargement of the head was present in no less than twenty-eight of the thirty-nine cases in the series An increase in the size of the head thus seems to occur more frequently than suggested in earlier reports It was further observed that ventricular dilatation was present in the majority of the cases, i e in thirty-two It occurred in twenty-five of the twenty-eight cases of enlargement of the head This suggests that ventricular dilatation may be the cause of the increase in size

The reason for the dilatation of the ventricles is so far unknown There seems however to be some justification for imaging a mechanism similar to the one acting in cases of basal arachnoiditis, in which fibrous membranes, formed within the cisterns, cause a blockage of the circulation of the cerebrospinal fluid The result is decreased resorbtion, secondary to which dilatation of the ventricles may develop Impairment of the circulation of the spinal fluid may also possibly arise from a subdural hygroma causing compression of closely related parts of the subarachnoid space The existence of such compression in the present series was indicated in the encephalograms by the absence of air in the subarachnoid space frequently noted on the side of the hygroma This was observed in a group comprising twenty-four of our cases In the other group, consisting of the remaining fifteen cases of our series, the hygroma was instead manifest as an increased distance between the inner table of the skull and the surface of the brain Widened ventricles in these two groups were present in twenty-three and nine cases, respectively The difference between the frequency of ventricular dilatation in the two groups favours the theory that compression of the subarachnoid space, with disturbance of the flow of the spinal fluid, actually existed in the first mentioned group In the other group, the one in which the hygroma was indicated in the encephalogram by the increased distance between the calvarium and the convexity of the brain, the air had passed to the convexities where it lay in the sulci These sulci often appeared wider than normal and the finding was then similar to that occurring in cortical atrophy This type of atrophy in cases of subdural hygroma was noted by INGRAHAM & MATSON, who also pointed out that it was often combined with signs of central atrophy, i e ventricular dilatation

The dilatation of the ventricles observed in this series may thus be divided into two kinds One probably represents external hydrocephalus and is caused by the

hygroma compressing the subarachnoid space, with impairment of the circulation of the spinal fluid and, as a consequence, its resorbtion The other kind seems to be secondary to atrophy of the brain tissue also evident as cortical changes, i e widened sulci (cf CRONQVIST 1968)

Since, as has been shown, ventricular dilatation seems to be reflected in the size of the head it was thought of interest to compare the skull size and the type of encephalographic changes characterized or suggesting the presence of a hygroma It was found that the group with no air passing over the convexity had a larger cranial index than the second group with air filled sulci The cranial [illegible]

of the mechanism of ventricular dilatation One is a new isotope method of gamma cisternography (DICHIRO) which permits studies of the pathways of the cerebrospinal fluid and of its resorbtion There are reasons to believe that the procedure will afford valuable information even from the viewpoint of diagnosis The other examination that should be carried out is postoperative encephalography The aim of such a follow up study would be to control the results of surgery as to passage of gas in the subarachnoid space or regression of the medial displacement of the surface of the brain registered prior to operation, and ventricular size

The observations on the six postoperative encephalographies available in this series are not conclusive The indications for the investigations were persistent symptoms or development of new neurologic signs Thus, no examination was performed in cases with obvious regression of clinical signs However, even in the present cases no further ventricular dilatation was present after operation, with the exception of one case with added basal arachnoiditis It should be pointed out that results of such an encephalographic follow up investigation as suggested may help in solving the disputed problems as to whether cases of hygroma should be actively treated or not

## SUMMARY

Thirty nine cases of subdural hygroma have been investigated with roentgen examination of the skull and encephalography An increase in the size of the head occurred in nearly all the cases Ventricular dilatation was noted in twenty eight cases most of which also had enlargement of the neurocranium A relationship between the two entities seems to exist Possible explanations and further studies are suggested

## ZUSAMMENFASSUNG

Ein Material von neununddreissig Fallen von subduralem Hygrom wurde mittels gewohnlichen Rontgenaufnahmen und mittels Enzephalographie untersucht. Vergrosserung des Schadels wurde in den meisten Fallen gesehen. Dilatation der Ventrikel war in achtundzwanzig Fallen vorhanden und in den meisten von diesen war auch der Schadel vergrössert. Diese zwei Erscheinungen durften sogar in Zusammenhang stehen. Erklarungsgrunde werden erlautert und weitere Untersuchungen vorgeschlagen.

## RÉSUMÉ

Trente neuf cas d'hydrome sous dural ont été examinés par radiographies du crâne et encephalographie. Il y avait dans presque tous les cas une augmentation évidente du volume de la tête. Il y avait une dilatation ventriculaire dans 28 cas dont la plupart avaient aussi une augmentation de volume du crâne. Il semble donc y avoir une relation entre ces deux anomalies. Les auteurs étudient les explications possibles de ces faits et proposent la poursuite de ces recherches.

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# NEUROTOXICITY OF ROENTGEN CONTRAST MEDIA

## Study of the blood-brain barrier in the rabbit following selective injection of contrast media into the internal carotid artery

by

P G JEPPSSON and TORD OLIN

The toxicity of modern contrast media injected intravenously is low When such media are administered intra arterially, however, toxicity is still a problem and this is especially true for the central nervous system Damage to the blood brain barrier following injection into the common carotid artery has been used as a parameter of the neurotoxicity of contrast media BROMAN & OLSSON (1948) developed this method in the rabbit trypan blue, which will not normally leak through the barrier being used as an indicator to demonstrate the lesions Similar studies have been made in other species, for example the dog (WHITELEATHER & DESAUSSURE 1956)

Indicators other than trypan blue have also been used, for example sodium fluorescein (SMITH *et coll* 1951), $^{131}$I human serum albumin (EDSTROM 1961) and $^{32}$P-orthophosphate (GONSETTE & ANDRE BALISAUX 1967) Another method of studying damage to the capillary endothelium of the brain has been *microscopy* following silver staining (MCCONNELL & MERSEREAU 1964) When the blood brain barrier is damaged, contrast medium leaks out into the brain parenchyma

This work was supported by a grant (No B69—23X—605—03) from the Swedish Medical Research Council Submitted for publication 26 February 1969

**Table 1**

*The various contrast media used in the present study*

| Trade name | Generic name and components | mg I/ml solution |
|---|---|---|
| Urografin 60 % | Diatrizoate Na 8 %<br>Megl 52 % | 290 |
| Urografin 76 % | Diatrizoate Na 10 %<br>Megl 66 % | 370 |
| Meglumine diatrizoate 60 % | Diatrizoate Megl 60 % | 283 |
| Sodium Isopaque 60 % | Metrizoate Na 60 % | 350 |
| Isopaque cerebral | Metrizoate Megl 59 1 %<br>Ca 1 13 % | 280 |
| Conray 300 | Iothalamate Na 50 % | 300 |
| Meglumine Conray 60 % | Iothalamate Megl 60 % | 282 |

and clonic seizure usually develops, this has been used as a method to estimate the neurotoxicity (OLIN & REDMAN 1967) EEG changes after intracarotid injection of contrast media have been studied by BLOOR et coll (1951) and LUNDERVOLD & ENGESET (1967) Damage to the spinal cord following an injection of contrast medium into the aorta has been interpreted histologically in long-term experiments (MARGOLIS et coll 1958)

TORNELL (1969) studied the frequency of pareses following contrast medium injection into the aorta, which was occluded distally The cardiovascular response, hypotonia and bradycardia, following an internal carotid injection has been used as an index of neurotoxicity (TORNELL 1968) No investigation seems to have been performed in which blood-brain barrier and cardiovascular reactions have been studied simultaneously in the same experiment The purpose of the present investigation was to compare the effects on the blood brain barrier and on the general circulation of some of the new contrast media now in use for cerebral angiography It was also considered necessary to compare a standardized injection technique at a fixed flow rate with previous methods Selective injection into the internal carotid artery of the rabbit was preferred in order to make the conditions more distinct This meant that a possible anomalous origin of the occipital artery from the internal carotid artery had to be taken into account (JEPPSSON & OLIN 1960)

*Material and Methods* Ninety-four rabbits, 2 kg in weight, were used The animals were anaesthetized with sodium pentobarbital (*mebumalnatrium 6 %*) given intravenously, artificial respiration was usually not used The left carotid artery was exposed and the external carotid artery ligated The most proximal

**Table 2**

*Results using Urografin 60 %*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inj time in sec | Application time in sec | Pulse/min Before | Pulse/min During | Blood pressure mm Hg Before | Blood pressure mm Hg Fall | Blood pressure mm Hg Rise | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K 31 | 10 0 | 1 5 | 38 2 | 65 5 | 68 8 | 300 | 60 | 105 | 0 | 40 | 0 | +(+) |
| K 32 | 10 0 | 1 2 | 37 2 | 65 0 | 64 4 | 240 | 210 | 75 | 15 | 35 | 8 | + |
| K 55 | 10 0 | 1 3 | 38 6 | 66 0 | 64 0 | — | — | 95 | 5 | 25 | — | +++ |
| K 24 | 5 0 | 2 5 | 38 4 | 33 0 | 32 4 | 330 | 330 | 125 | 5 | 40 | 3 | +++ |
| K 28 | 5 0 | 2 6 | 39 0 | 32 5 | 32 0 | 270 | 180 | 110 | 0 | 40 | 0 | ++ |
| K 29 | 5 0 | 3 2 | 39 2 | 31 0 | 30 4 | 300 | 240 | 100 | 10 | 30 | 5 | neg |
| K 23 | 2 5 | 1 9 | 37 0 | 16 0 | 17 2 | 240 | 240 | 120 | 5 | 15 | 7 | neg |
| K 26 | 2 5 | 1 5 | 38 6 | 18 5 | 19 6 | 270 | 270 | 100 | 0 | 17 | 0 | neg |
| K 27 | 2 5 | 2 5 | 39 0 | 16 0 | 16 4 | 300 | 300 | 115 | 18 | 45 | 3 | ++ |

part of the internal carotid artery was inspected for an anomalously arising occipital artery, which was ligated when present The common carotid artery was ligated caudally and then cannulated with a polythene catheter with an inner diameter of 1 15 mm (PE 160, Clay Adams, New York, USA) A burr-hole was made in the parietal region of the skull on the left side The femoral vein and artery were cannulated with polythene catheters (PE 160), the vein being connected to a saline container and the artery to an electromanometer (Elema Schonander) for measurement of the blood pressure and pulse rate The catheter in the carotid artery was connected to a 10 ml syringe, which was placed in an infusion machine (CLEMENTZ & OLIN 1961) The flow rate of the injection that expelled the blood in the pial vessels during the whole injection time was determined in pilot experiments to be about 0 16 ml/s, and this speed of injection was applied throughout the subsequent investigation The time during which the pial blood vessels were rinsed of blood will be referred to as the application time In contrast to previous authors, such as BROMAN & OLSSON (1956) and

whole time d

the length of the injection The application was checked by inspection through the burr hole in the skull The duration of the injection, the application time and the blood pressure and pulse rate were recorded on a polygraph (Mingograph 24, Elema Schonander) After the injection of the contrast medium, 100 ml of trypan blue 0 5 % at room temperature were infused into the femoral vein

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Before* | *During* | Before | Fall | Rise | | |
| K 31 | 10.0 | 1.5 | 38.2 | 65.5 | 68.8 | 300 | 60 | 105 | 0 | 40 | 0 | +(+) |
| K 32 | 10.0 | 1.2 | 37.2 | 65.0 | 64.4 | 240 | 210 | 75 | 15 | 35 | 8 | + |
| K 55 | 10.0 | 1.3 | 38.6 | 66.0 | 64.0 | — | — | 95 | 5 | 25 | — | +++ |
| K 24 | 5.0 | 2.5 | 38.4 | 33.0 | 32.4 | 330 | 330 | 125 | 5 | 40 | 3 | +++ |
| K 28 | 5.0 | 2.6 | 39.0 | 32.5 | 32.0 | 270 | 180 | 110 | 0 | 40 | 0 | ++ |
| K 29 | 5.0 | 3.2 | 39.2 | 31.0 | 30.4 | 300 | 240 | 100 | 10 | 30 | 5 | neg |
| K 25 | 2.5 | 1.9 | 37.0 | 16.0 | 17.2 | 240 | 240 | 120 | 5 | 15 | 7 | neg |
| K 26 | 2.5 | 1.5 | 38.6 | 18.5 | 19.6 | 270 | 270 | 100 | 0 | 17 | 0 | neg |
| K 27 | 2.5 | 2.5 | 39.0 | 16.0 | 16.4 | 300 | 300 | 115 | 18 | 45 | 3 | ++ |

part of the internal carotid artery was inspected for an anomalously arising occipital artery, which was ligated when present. The common carotid artery was ligated caudally and then cannulated with a polythene catheter with an inner diameter of 1.15 mm (PE 160, Clay Adams, New York, USA). A burr-hole was made in the parietal region of the skull on the left side. The femoral vein and artery were cannulated with polythene catheters (PE 160), the vein being connected to a saline container and the artery to an electromanometer (Elema Schonander) for measurement of the blood pressure and pulse rate. The catheter in the carotid artery was connected to a 10 ml syringe, which was placed in an infusion machine (CLEMENTZ & OLIN 1961). The flow rate of the injection that expelled the blood in the pial vessels during the whole injection time was determined in pilot experiments to be about 0.16 ml/s and this speed of injection was applied throughout the subsequent investigation. The time during which the pial blood vessels were rinsed of blood will be referred to as the application time. In contrast to previous authors, such as BROMAN & OLSSON (1956) and JEPPSSON (1962), the application time in the present work means the whole time during which the blood in the pial vessels was expelled, regardless of the length of the injection. The application was checked by inspection through the burr hole in the skull. The duration of the injection, the application time and the blood pressure and pulse rate were recorded on a polygraph (Mingograph 24, Elema Schonander). After the injection of the contrast medium, 100 ml of trypan blue 0.5 % at room temperature were infused into the femoral vein

**Table 3**

*Results using Urografin 76 %*

| Rabbit | Contrast medium vol. ml | Body wt kg | Body temp. at inj. °C | Inject. time in sec | Application time in sec | Pulse/min Before | Pulse/min During | Blood pressure mm Hg Before | Blood pressure mm Hg Fall | Blood pressure mm Hg Rise | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K5 | 10.0 | 2.8 | — | 61.0 | 61.2 | 215 | 65 | 105 | 10 | 5 | 4 | ++++ |
| K56 | 10.0 | 2.4 | 39.0 | 63.5 | 66.0 | 240 | 90 | 115 | 5 | 10 | 3 | + |
| K57* | 10.0 | 2.0 | 38.0 | — | — |  | — | — | — |  |  | ++++ |
| K6 | 5.0 | 1.5 | — | 34.0 | 34.0 | 120 | 115 | 100 | 0 | 0 | 0 | ++ |
| K59 | 5.0 | 2.3 | 39.2 | 33.0 | 31.0 | 210 | 90 | 105 | 35 | 60 | 6 | ++ |
| K60 | 5.0 | 2.7 | 38.3 | 33.0 | 30.5 | 270 | 300 | 115 | 20 | 10 | 6 | +++ |
| K7 | 2.5 | 2.3 |  | 16.0 | 13.0 | 275 | 180 | 130 | 0 | 65 | 0 | +++ |
| K62 | 2.5 | 1.5 | 38.2 | 17.0 | 17.0 | 300 | 240 | 115 | 0 | 60 | 0 | +(+) |
| K63 | 2.5 | 2.2 | 39.2 | 17.0 | 17.0 | 270 | 240 | 65 | 0 | 80 | 0 | +++ |
| K8 | 1.25 | 2.1 | — | 7.5 | 8.2 | 205 | 210 | 120 | 2 | 47 | 0 | + |
| K11 | 1.25 | 1.9 | 36.4 | 8.0 | 8.4 | 185 | 210 | 120 | 0 | 10 | 0 | (+?) |
| K117 | 1.25 | 2.5 | 39.0 | 8.0 | 9.0 | 240 | 240 | 85 | 10 | 5 | 3 | (+) |

*The left occipital artery arose from the internal carotid artery.

After an infusion time of about 15 minutes, the animal was killed and the cerebral vessels rinsed with 300 ml saline solution 0.9 % through a catheter inserted cranially into the aorta. The brain was fixed in situ with 200 ml formalin 10 % introduced via the catheter in the aorta. The degree of injury to the brains was rated and the latter were then examined microscopically as described by JEPPSSON (1962). The contrast media used are listed in Table 1; they were at room temperature (20—24 °C) when injected. The rectal temperature was recorded with a thermometer inserted 9 cm above the anus.

The dose was varied from 10.0 ml downwards in order to evaluate the toxicity of different contrast media. The dose was halved to 5.0, 2.5, 1.25 and 0.65 ml until no or only very slight damage to the blood-brain barrier occurred. Three animals were used at each dose level. Some experiments were used as controls to ensure that the technique used did not cause any lesion of the blood-brain barrier. The anatomy of the internal carotid artery on the injected side was checked by post mortem angiography with a barium suspension.

## Results

*Urografin 60 %* (Table 2). Nine animals were used, equally divided between doses of 10.0, 5.0 and 2.5 ml. No animal had a maximal lesion. With the lowest

**Table 4**

*Results using meglumine diatrizoate 60 %*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inject time in sec | Application time in sec | Pulse/min | | Blood pressure mm Hg | | | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Before | During | Before | Fall | Rise | | |
| K101 | 10.0 | 1.9 | 38.0 | 63.5 | 63.5 | 300 | 270 | 95 | 0 | 30 | 0 | ++ |
| K115 | 10.0 | 2.2 | 38.0 | 65.5 | 68.0 | 240 | 240 | 85 | 0 | 0 | 0 | +++ |
| K116* | 10.0 | 2.5 | 36.2 | 64.0 | 91.0 | 270 | 180 | 60 | 5 | 15 | 3 | neg |
| K102 | 5.0 | 1.8 | 39.0 | 33.0 | 32.0 | 300 | 300 | 85 | 10 | 40 | 4 | ++ |
| K112 | 5.0 | 3.4 | 38.4 | 33.0 | 33.0 | 300 | 300 | 145 | 20 | 45 | 4 | ++++ |
| K114 | 5.0 | 2.4 | 38.7 | 33.0 | 33.0 | 240 | 180 | 50 | 0 | 30 | 0 | + |
| K103 | 2.5 | 2.2 | 38.2 | 16.5 | 15.0 | 240 | 240 | 80 | 5 | 5 | 3 | (+?) |
| K108 | 2.5 | 2.0 | 38.0 | 16.0 | 15.5 | 270 | 240 | 125 | 0 | 10 | 0 | (+) |
| K109 | 2.5 | 2.0 | 38.0 | 16.5 | 16.5 | 270 | 240 | 110 | 35 | 10 | 9 | (+) |

*Injection on the right side Left common carotid artery ligated

dose, no staining of the brain was observed in two of the three animals The effect of the injection on the pulse rate was almost negligible One animal, however, developed marked bradycardia with the 10.0 ml dose The fall in blood pressure was also small and bore no relation of the amount of contrast medium injected The rise in blood pressure was evident but apparently did not vary with the dose

*Urografin 76 %* (Table 3) Fifteen animals were used, equally divided between doses of 10.0, 5.0, 2.5 and 1.25 ml A small lesion in the blood brain barrier was present in the last group Two of three animals in the 10.0 ml group had a maximal lesion of the brain Rather marked bradycardia occurred with the two highest doses, the two smallest doses, however, produced only slight bradycardia The fall in blood pressure was more obvious in the groups given 10.0 and 5.0 ml than in the other two groups The rise in blood pressure did not seem to depend on the dose

*Meglumine diatrizoate 60 %* (Table 4) Nine animals were used, equally divided between doses of 10.0 5.0 and 2.5 ml Damage to the blood brain barrier was slight with the lowest dose One animal had a maximal lesion which occurred with a dose of 5 ml The application time in one of the animals that received an injection of 10.0 ml of contrast medium was one third longer than

**Table 5**

*Results using Sodium Isopaque 60 %*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inject time in sec | Application time in sec | Pulse/min | | Blood pressure mm Hg | | | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Before | During | Before | Fall | Rise | | |
| K43 | 10 0 | 1 5 | 38 0 | 67 0 | 67 2 | 300 | 120 | 95 | 10 | 60 | 3 | ++++ |
| K73 | 10 0 | 2 5 | 39 4 | 65 0 | 68 0 | 300 | 60 | 130 | 30 | 45 | 4 | ++++ |
| K44 | 5 0 | 1 4 | 38 0 | 34 5 | 35 2 | 315 | 165 | 95 | 5 | 50 | 2 | ++ |
| K75 | 5 0 | 2 5 | 39 2 | 33 0 | 34 5 | 270 | 85 | 110 | 20 | 65 | 10 | ++++ |
| K77 | 5 0 | 2 1 | 38 8 | 32 5 | 32 5 | 240 | 150 | 100 | 0 | 60 | 0 | ++++ |
| K47 | 2 5 | 1 6 | 37 4 | 16 5 | 18 2 | — | — | — | — | — | — | +++ |
| K78 | 2 5 | 2 4 | 38 0 | 16 5 | 15 5 | 270 | 270 | 95 | 5 | 65 | 3 | + |
| K79 | 2 5 | 1 4 | 38 2 | 17 0 | 17 0 | 300 | 90 | 95 | 5 | 60 | 2 | ++ |
| K49 | 1 25 | 1 6 | 37 8 | 7 5 | 9 8 | 205 | 170 | 95 | 15 | 30 | 7 | ++(+) |
| K50 | 1 25 | 1 6 | 37 2 | 7 5 | 8 6 | 275 | 240 | 115 | 5 | 40 | 4 | +(+) |
| K80 | 1 25 | 1 4 | 38 2 | 8 0 | 10 5 | 270 | 240 | 60 | 5 | 30 | 2 | (+) |
| K52 | 0 65 | 1 5 | 37 0 | 4 0 | 4 8 | 300 | 270 | 115 | 0 | 15 | 0 | (+?) |
| K53 | 0 65 | 2 0 | 37 2 | 4 5 | 8 0 | 240 | 210 | 130 | 25 | 105 | 4 | (+?) |
| K54 | 0 65 | 1 7 | 37 0 | 4 5 | 7 0 | 300 | 270 | 125 | 15 | 25 | 3 | +++ |

usual This was probably due to the fact that both common carotid arteries were ligated As the expulsion of blood in the pial vessel was not obtained on injection into the left carotid artery an injection was performed on the right side The pulse rate was not affected by the injection of contrast medium The fall in blood pressure was usually small or absent, any rise was moderate and not correlated to the dose

*Sodium Isopaque 60 %* (Table 5) Two animals were injected with 10 0 ml and three animals were each given 5 0, 2 5, 1 25 and 0 65 ml Damage to the blood-brain barrier was slight on injection of 0 65 ml Four animals had maximal lesions with doses of 10 0 and 5 0 ml The fall in pulse rate was marked in the two highest dose groups, the bradycardic response decreased with the dose The fall in blood pressure was less severe and was not related to the dose, the rise in blood pressure seemed to increase with the higher doses

*Isopaque Cerebral 60 %* (Table 6) Nine animals were injected, equally divided between doses of 10 0, 5 0 and 2 5 ml No animal developed a maximal lesion Damage to the barrier was slight in the 2 5 ml group The effect on the

**Table 6**

*Results using Isopaque Cerebral 60 %*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inject time in sec | Application time in sec | Pulse/min | | Blood pressure mm Hg | | | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Before | During | Before | Fall | Rise | | |
| K14 | 10 0 | 2 0 | 38 2 | 64 0 | 63 6 | 270 | 270 | 107 | 13 | 20 | 6 | +++ |
| K64 | 10 0 | 3 7 | 38 8 | 65 0 | 65 0 | 270 | 270 | 85 | 5 | 50 | 3 | (+) |
| K65 | 10 0 | 2 1 | 38 5 | 65 0 | 64 5 | 270 | 240 | 120 | 0 | 0 | 0 | + |
| K16* | 5 0 | 3 1 | 37 4 | 32 0 | 30 4 | 250 | 220 | 110 | 13 | 5 | 9 | + |
| K22 | 5 0 | 1 8 | 38 0 | 32 0 | 32 0 | 250 | 220 | 180 | 10 | 25 | 5 | (+) |
| K23 | 5 0 | 3 2 | 38 0 | 32 0 | 32 0 | 300 | 280 | 125 | 0 | 30 | 0 | +(+) |
| K17* | 2 5 | 1 7 | 39 0 | 15 5 | 14 8 | 295 | 265 | 110 | 13 | 20 | 2 | (+) |
| K19 | 2 5 | 2 2 | 39 0 | 16 5 | 16 2 | 260 | 235 | 120 | 18 | 38 | 5 | (+?) |
| K21 | 2 5 | 2 2 | 39 2 | 16 0 | 16 0 | 275 | 270 | 115 | 25 | 15 | 3 | (+) |

* An anomalous occipital artery was ligated before the injection

pulse rate was slight A definite fall in blood pressure usually occurred but did not seem to be related to the amount of medium injected The rise in blood pressure was also definite although not related to the dose

*Conray 300* (Table 7) Twelve rabbits were divided equally between doses of 10 0, 5 0, 2 5 and 1 25 ml Two animals had a maximal lesion of the blood brain barrier with doses of 10 0 and 5 0, respectively At the 1 25 ml dose, two of three animals developed no lesion A rather severe fall in pulse rate occurred with the higher doses The fall in blood pressure was small and occurred only in some of the animals belonging to the highest dose groups. The rise in blood pressure was marked and especially so with the higher doses

*Meglumine Conray 60 %* (Table 8) Two rabbits were given 10 0 ml into the internal carotid artery, and three animals were each given 5 0, 2 5 and 1 25 ml One animal developed a maximal lesion of the blood brain barrier with the highest dose The smallest dose produced no effect upon the barrier The bradycardic response was virtually absent A fall in blood pressure was the rule but apparently was not dependent on the dose, the rise in blood pressure was obvious and seemed to increase with the dose

*Results common to the different series* The expulsion of the blood from the pial vessels was complete during the intracarotid injection in the experiments

**Table 7**

*Results using Conray 300*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inj time in sec | Application time in sec | Pulse/min Before | Pulse/min During | Blood pressure mm Hg Before | Blood pressure mm Hg Fall | Blood pressure mm Hg Rise | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K33 | 10.0 | 1.4 | 37.8 | 63.0 | 63.6 | — | — | 80 | 0 | 20 | 0 | ++(+) |
| K66 | 10.0 | 2.1 | 39.0 | 64.5 | 64.5 | 240 | 75 | 55 | 5 | 75 | 6 | ++(+) |
| K67 | 10.0 | 1.9 | 39.0 | 63.5 | 64.5 | 300 | 120 | 115 | 0 | 65 | 0 | ++++ |
| K34 | 5.0 | 1.4 | 37.3 | 32.5 | 33.6 | 300 | 90 | 115 | 10 | 35 | 2 | +(+) |
| K68 | 5.0 | 2.2 | 38.4 | 33.0 | 33.6 | 300 | 240 | 105 | 20 | 55 | 5 | ++(+) |
| K71 | 5.0 | 2.3 | 38.0 | 32.5 | 33.0 | 270 | 75 | 95 | 0 | 50 | 0 | ++++ |
| K35 | 2.5 | 1.7 | 37.0 | 16.5 | 16.8 | 270 | 240 | 80 | — | 30 | — | ++ |
| K41 | 2.5 | 2.4 | 38.2 | 17.0 | 16.0 | — | — | — | — | — | — | +++ |
| K42 | 2.5 | 1.6 | 38.0 | 17.0 | 16.4 | 240 | 210 | 105 | 0 | 30 | 0 | ++ |
| K36 | 1.25 | 1.4 | 37.0 | 7.5 | 8.0 | 270 | 240 | 105 | 0 | 45 | 0 | neg |
| K39 | 1.25 | 1.7 | 38.2 | 8.5 | 8.2 | 210 | 210 | 60 | 0 | 10 | 0 | neg |
| K40 | 1.25 | 1.7 | 37.0 | 9.0 | 8.0 | 240 | 210 | 70 | 0 | 55 | 0 | ++ |

**Table 8**

*Results using Meglumine Conray 60 %*

| Rabbit | Contrast medium vol ml | Body wt kg | Body temp at inj °C | Inj time in sec | Application time in sec | Pulse/min Before | Pulse/min During | Blood pressure mm Hg Before | Blood pressure mm Hg Fall | Blood pressure mm Hg Rise | Duration of fall in sec | Degree of injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K81 | 10.0 | 1.6 | 38.2 | 64.0 | 64.0 | — | — | — | 0 | 0 | 0 | ++++ |
| K100 | 10.0 | 2.8 | 39.8 | 63.5 | 63.0 | 270 | 300 | 65 | 5 | 50 | 3 | +++ |
| K82 | 5.0 | 1.8 | 39.0 | 33.0 | 32.0 | 270 | 240 | 95 | 15 | 35 | 5 | + |
| K93 | 5.0 | 2.8 | — | 32.5 | 31.0 | 300 | 270 | 110 | 20 | 40 | 6 | +++ |
| K97 | 5.0 | 2.4 | 39.0 | 33.0 | 31.0 | 270 | 270 | 100 | 5 | 30 | 2 | ++ |
| K83 | 2.5 | 2.9 | 38.2 | — | 16.5 | 270 | 270 | 55 | 0 | 65 | 0 | (+?) |
| K84 | 2.5 | 3.5 | 38.0 | 16.0 | 16.0 | 210 | 195 | 95 | 15 | 20 | 5 | + |
| K85 | 2.5 | 3.5 | 39.0 | 17.5 | 19.0 | 240 | 240 | — | 0 | 0 | 0 | ++(+) |
| K86 | 1.25 | 1.5 | 38.0 | 8.5 | 9.5 | 225 | 225 | 55 | 0 | 0 | 0 | neg |
| K90 | 1.25 | 3.0 | 38.2 | 9.0 | 9.0 | 270 | 270 | 90 | 30 | 0 | 10 | neg |
| K91 | 1.25 | 2.4 | 39.0 | 8.5 | 7.0 | 330 | 300 | 115 | 0 | 0 | 0 | neg |

Table 9

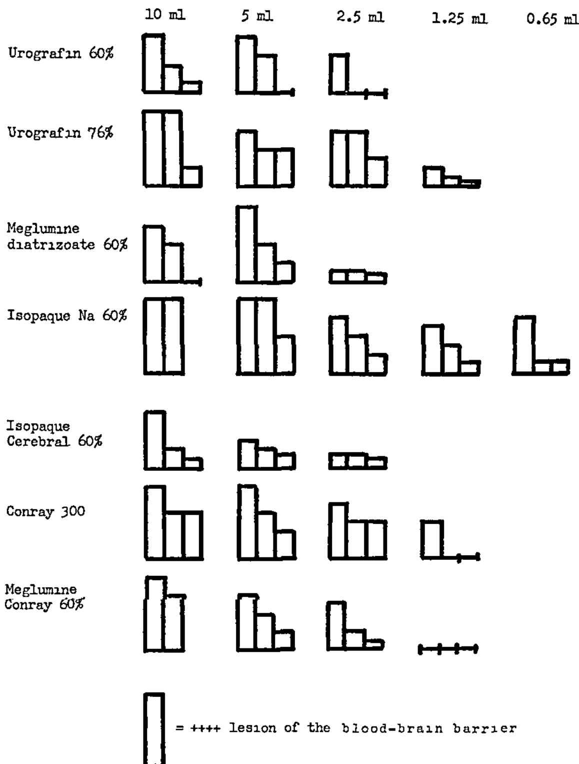
*Distribution of injury between different areas of vascular supply — The figures denote number of animals — Nine brains were negative*

| Experimental series | Total number of animals | Left internal carotid area most damaged or same as others | Left internal carotid area damaged | | Left internal carotid area negative or slightly damaged | |
|---|---|---|---|---|---|---|
| | | | Right internal carotid area most damaged | Vertebral area most damaged | Right internal carotid area most damaged | Vertebral area most damaged |
| Urografin 60 % | 9 | 4 | | 2 | | |
| Urografin 76 % | 12 | 9 | 1 | 2 | | |
| Meglumine diatrizoate 60 % | 9 | 6 | | | 1 | 1 |
| Sodium Isopaque 60 % | 14 | 7 | | 1 | 1 | 5 |
| Isopaque Cerebral | 9 | 6 | | | | 3 |
| Conray 300 | 12 | 3 | 2 | | 3 | 2 |
| Meglumine Conray 60 % | 11 | 6 | 1 | | | 1 |
| Total | 76 | 41 | 4 | 5 | 5 | 12 |
| | | | 26 | | | |

presented above In 18 animals, the expulsion of the blood was not complete, i e the blood returned during the injection, or the expulsion was intermittent or partial In ten of these eighteen animals the occipital artery arose anomalously from the internal carotid artery on the injected side In one of the animals an occipital artery from the internal carotid artery was located before injection and ligated but in spite of this the expulsion of blood was incomplete In one animal the internal carotid artery was ligated by mistake In four animals no explanation was found for the incomplete expulsion of the blood from the pial vessels These eighteen animals are not included in the tables Complete expulsion from the pial vessels occurred in seven animals with an anomalous occipital artery One of them is included in the present series as it had a maximal lesion of the blood-brain barrier The other six animals are excluded

Both the injection time and the application time were proportional to the amount of contrast medium injected

The lesion of the barrier was usually most severe in the area of the internal




Survey of the degree of injury to the blood brain barrier in the different experimental series

carotid artery into which the injection was made, i e the left side (Table 9) However, in nine animals the contralateral carotid area was the most damaged In five of these nine animals the left internal carotid area was affected only slightly or not at all The area of the vertebral artery was the most damaged in seventeen animals, in twelve of these the left internal carotid area was only slightly damaged

The lesion was usually uniform or patchy blue in colour The brain appeared red to the naked eye in the cases with stasis Blue staining of the walls of the vessels and diffuse staining of the parenchyma were observed at microscopy Staining of the nucleus of parenchymal cells was sometimes present Staining of the endothelial cell nuclei was virtually absent The vessels were packed with red blood corpuscles in the cases with stasis

*Comparison of the series* The effect of the roentgen contrast media on the blood brain barrier is illustrated in the accompanying figure Urografin 60 %, Isopaque Cerebral and meglumine diatrizoate 60 % produced slight or no lesions at the 2 5 ml dose These three contrast media appear to have the lowest toxicity among those tested We consider however that the data do not selectively favour any of these three contrast media above the others The figure also indicates that Urografin 76 %, Conray 300 and Meglumine Conray reach the 'non toxic' level at a dose of 1 25 ml Isopaque 60 % could still produce a slight lesion in a dose of about 0 65 ml and was thus the most toxic of the seven different contrast media tested

The cardiovascular reactions were most severe with roentgen contrast media containing sodium Bradycardia appeared particularly at high doses of these contrast media The fall in blood pressure was not dependent on the dose, with the exception of Urografin 76 % The rise in blood pressure was most marked with high doses of Sodium Isopaque, Conray 300 and Conray Meglumine The rise in blood pressure occurred more at random with injections of Urografin 76 % and Isopaque Cerebral

Table 9 indicates that Sodium Isopaque 60 % and Conray 300 are those contrast media that contribute most to a paradoxical location of a lesion of the blood brain barrier

The material was grouped according to the degree of the injury to the blood brain barrier The four plus group contained most of the cases of marked bradycardia the negative group produced the smallest response The other cardiovascular parameters presented no tendency to be related to the degree of lesion only those contrast media that contained meglumine were investigated in the same way The heart rate fell with decreasing dose The blood pressure reactions were not related to the degree of lesion of the barrier

## Discussion

The technique used in the present investigation was preferred for several reasons. The rabbit has a better defined anatomy of the cerebral vessels than the animals used in similar experiments (JEPPSSON & OLIN 1960). By ligation of the internal carotid artery, and by taking an anomalous occipital artery into consideration, it is possible to ensure that the injected volume goes to the brain. Thus a more quantitative estimate of the amount of contrast medium necessary for provoking a lesion of the blood-brain barrier is possible.

Selective injection into the internal carotid artery cannot be made in the dog, the cat or the guinea-pig for anatomical reasons (see ASK-UPMARK 1935). Quantitative administration is therefore impossible in these animals but nevertheless they have been widely used. GONSETTE & ANDRE-BALISAUX (1967) used the guinea-pig, the dog was employed by HARRINGTON et coll. (1966), BASSETT et coll. (1953), KODAMA et coll. (1963), SMOLIK & NASH (1964) and FISCHER & ECKSTEIN (1961). CRAVER et coll. (1968) used cats in a study of the penetration of salts of diatrizoate compounds into the cerebral parenchyma. Their reasons for selecting cats was that the cerebral circulation of the cat was more like that of man than that of the dog. Injection has hitherto generally been made manually. STEINWALL (1958) preferred this method as it was possible to adjust the injection rate to the degree of expulsion of the blood from the pial vessels. In the present experiments an injection rate was chosen that gave complete expulsion from the vessels in pilot studies, when the above criteria of selective injection were fulfilled. By the use of an injection machine the injection rate could be standardized, the injection parameters are thus better defined on this point as well.

Expulsion of the blood from the pial vessels was sometimes not complete in spite of the standardization. This was explained in ten experiments by an anomalous occipital artery that was not discovered until the post-experimental roentgen examination of the internal carotid artery. It is a reasonable assumption that at a given injection rate an 'extra' vessel steals contrast medium from the vascular territory for which the dose is intended. Complete expulsion was *however* also obtained in experiments where an anomalous occipital artery was present. This might be explained by the dose being sufficient for the actual vascular territory in spite of this anomaly. It also happened that the expulsion of the blood was incomplete in spite of a normal vascular anatomy. No obvious explanation so far exists for this disturbing fact. However, it may be assumed that the vascular territory in these animals was too large for the actual injection rate. The effect on the blood-brain barrier of incomplete expulsion was obvious in some experiments as no lesion was produced, it may be argued that the lesion obtained would

have been more severe if the expulsion had been complete It is also possible in the case of an anomalous occipital artery to argue that the whole dose had not entered the target area so that the lesion was less marked than if the whole dose had entered the cerebral vessels It is for this reason that such experiments were excluded Great variation in the degree of damage with the same dose however still existed It is clear that research workers who study the injury to the blood-brain barrier by intracarotid injection without observing the degree of expulsion from the vessels in the injected area work with an uncontrolled source of error

The total volume of contrast solution that has to be given to produce barrier damage is quite small with selective injection into the internal carotid artery as compared with the huge amount necessary to obtain corresponding damage to the barrier with injection into the common carotid artery With injection into the latter the large volume of hypertonic solution severely disturbs the general circulation and therefore the jugular veins have to be cut Due to the small amount used at selective injection into the internal carotid artery, the recirculation of the contrast medium can be disregarded

The application time was closely correlated to the injected volume and to the injection time in the present study In earlier studies (JEPPSSON 1962), the volume injected as well as the injection time were found to be closely correlated to the application time In the choice between suitable indicators to demonstrate damage to the blood brain barrier we selected trypan blue, this has been widely used for many years (BROMAN & OLSSON 1948, 1956, JEPPSSON 1962) RIHSA $^{131}$I human serum albumin, was compared with $^{51}CrCl_3$ by EDSTROM (1961) STEINWALL & KLATZO (1965) studied cold injuries and used Evans blue and fluorescein as indicators BAKEY (1956) stated that $^{32}$P was a more sensitive agent than vital dyes However, he came to this conclusion by comparing his own experiments with $^{32}$P with similar experiments performed with vital dyes as reported in the literature MOORE (1953) studied *the effect* on the barrier produced by the injection of Diodrast into the common carotid artery in the rabbit He used either sodium fluorescein or trypan blue as an indicator of injury to the barrier He failed however, to find any difference in sensitivity between the two test substances *GONSETTE & ANDRE BALISAUX* (1967) stated that radioactive isotopes were more sensitive than trypan blue in detecting small lesions of the blood brain barrier WHITELEATHER & DESAUSSURE (1956) expressed the opinion that clinical signs, such as epileptic seizures, were more sensitive than trypan blue The appearance of a seizure is usually inhibited by deep anaesthesia The narcosis had to be rather deep in the present experiments due to the dissection in the neck

So far no conclusive report regarding any substance superior to trypan blue in detecting an experimental injury to the blood brain barrier seems to have

been published. Due to the above-mentioned reasons and as the trypan blue method is easy to handle we have preferred this technique.

Cardiovascular reactions to injection of roentgen contrast media into the carotid artery have been studied by LINDGREN & TORNELL (1958). They measured the blood pressure and the pulse rate at injections of sodium acetrizoate into the carotid artery in cats. Bradycardia and hypotension occurred. They considered the first phase of the blood pressure fall to be secondary to the bradycardia, which was effectuated via the vagal nerves, and the second phase of the *hypotension to be due to diminished vasoconstrictor discharge.* They judged both phases to be related by the direct action of the medium injected on the vasomotor centres in the brain. The cardiovascular responses to the injection of contrast media into the common carotid artery of the dog were studied by FISCHER & ECKSTEIN (1961) and FISCHER & CORNELL (1965). They found that the sodium salts of diatrizoate, iothalamate and metrizoate gave more reactions than the corresponding methylglucamine salts; among the sodium salts, the diatrizoates caused the smallest reactions. CORNELL & FISCHER (1967), using the same technique, reported that a mixture of sodium and methylglucamine calcium and magnesium metrizoate altered the arterial blood pressure and heart rate more than pure methylglucamine metrizoate. A corresponding investigation with sodium iothalamate produced similar results. Clinical studies during carotid angiography (GREITZ & TORNELL 1967, GREITZ, TELENIUS & TORNELL 1967, TORNELL 1968, LUNDERVOLD & ENGESET 1967) have indicated that bradycardia to some extent may be due to the sodium ion of the contrast medium.

Bradycardia was also especially marked with high doses of sodium salts in the present studies in rabbits. Hypotension, however, has no direct connection with the sodium, except with Urografin 76 %. The hypertension which succeeds the *hypotension always occurs with the sodium salts (Isopaque 60 % and Conray 300)* and Meglumine Conray. The cardiovascular reactions that we observed have thus been especially associated with the presence of sodium ions. The sodium salts examined also present the highest neurotoxicity as assessed by the blood brain barrier technique. Since the bradycardia with injections of meglumine salts had a negative correlation to the barrier lesion, and since the reactions of the blood pressure varied irrespective of the lesion, the cardiovascular reactions are not a measure of the neurotoxicity as judged by lesions of the barrier. It should be noted, however, that the common carotid artery was ligated proximally in the experiments. On the other hand, the rabbit has a well-developed circle of Willis, so that the blood will generally rinse away the contrast medium from the brain vessels as soon as the injection is completed. In accordance with this the application time and the injection time are of about the same duration. No obvious correlation between the neurotoxicity and the cardiovascular reaction was found.

in some other studies of the neurotoxicity with injection into the vertebral artery (OLIN & REDMAN 1967) No brain vessels were occluded in these previous examinations It would appear that the cardiovascular reactions are essentially a measure of the sodium percentage of the contrast media and not necessarily a measure of the neurotoxicity The lesions of the barrier with a paradoxical location occur at the highest frequency for roentgen contrast media containing a high percentage of sodium salt These contrast media also produce the most severe cardiovascular reactions

The present studies of the effect of some modern roentgen contrast media on the blood brain barrier are on the whole in accordance with similar studies made by other investigators Thus, sodium salts have produced a more intense lesion of the barrier with a certain dose as compared with a corresponding amount of a meglumine salt in the same roentgen contrast medium (KODAMA et coll 1963, SALVESEN et coll 1967b, GONSETTE & ANDRE-BALISAUX 1967) HARRINGTON et coll (1966), however, evaluated the damage to the blood brain barrier in dogs following injections into the internal carotid artery and found that only 43 % of the animals had lesions of the blood brain barrier after Hypaque 50 % (sodium) as compared to 75 % after meglumine diatrizoate These investigators employed the distribution of the lesion as a measure of the neurotoxicity instead of the degree of lesion The diverging results might have been due to the different principles of evaluation of the degree of lesion of the barrier Concerning the methylglucamine salts, we found Meglumine Conray 60 % somewhat more toxic than meglumine diatrizoate 60 % Urografin, which is a methylglucamine salt with some addition of a sodium salt, also belongs to the group of low toxicity in the studies, when used in 60 % solution When, however, its concentration was increased to 76 %, the toxicity increased considerably

GONSETTE & ANDRE BALISAUX (1967) found the following contrast media to be equally toxic Urografin 60 %, Meglumine Conray 60 %, Isopaque Cerebral 60 % and Sodium Isopaque 45 % (balanced with Ca and Mg) SALVESEN *et coll* (1967b) reported, in accordance with our studies, that Meglumine Conray was more toxic than Isopaque Cerebral They stated, however, that Urografin 60 % was somewhat more toxic than Isopaque Cerebral These investigators were also able to demonstrate that a suitable addition of calcium salt to methylglucamine metrizoate diminished the toxicity as compared to the pure methylglucamine salt A corresponding calcium salt addition to methylglucamine diatrizoate is not possible due to the low solubility of the calcium diatrizoate

In spite of the standardized injection technique used, and although each animal was thoroughly examined for the presence of an anomalous occipital artery, there was still a large variation in the degree of lesion of the blood brain barrier at a certain amount of contrast medium The range of body temperature was

too small to explain these differences (JEPPSSON 1962). The discrepancy in the degree of lesion of the barrier in animals that received the same dose might be due to a difference in the vulnerability of the blood-brain barrier of the individual animals. It is therefore necessary to test each dose on at least three animals.

## SUMMARY

The toxicity of certain modern roentgen contrast media was studied with selective injection into the internal carotid artery of rabbits and evaluated by damage to the blood brain barrier and cardiovascular reactions. The latter (initial hypotension and bradycardia) were severe for contrast media containing pure sodium salts but were not necessarily a measure of the neurotoxicity as estimated by studies of the barrier.

## ZUSAMMENFASSUNG

Die Toxicität verschiedener moderner Kontrastmittel wurde bei selektiver Injektion der Carotis interna an Kaninchen durch Beurteilung der Beschädigung der Bluthirnschranke und der cardiovaskulären Störungen analysiert. Hochgradige cardiovaskuläre Störungen (Hypotonie und Bradykardie) wurden mit den Kontrastmitteln, die reine Natriumsalze enthalten, beobachtet, ohne jedoch notwendigerweise als ein Mass der Neurotoxicität mit Hinsicht auf die Bluthirnschranke betrachtet zu werden.

## RÉSUMÉ

Les auteurs ont étudié la toxicité de certains moyens de contraste radiologique modernes par l'injection sélective de l'artère carotide interne de lapins et l'ont évaluée par les dommages de la barrière hématoencéphalique et par les réactions cardio-vasculaires. Ces réactions (hypertension initiale et bradycardie) ont été graves avec les moyens de contraste contenant des sels de sodium purs mais ne mesurent pas nécessairement la neurotoxicité estimée d'après les études de la barrière hématoencéphalique.

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# ARTERIOGRAPHIC APPEARANCES OF PHAEOCHROMOCYTOMAS

by

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Recent progress in the investigation of arterial hypertension has resulted in biochemical and pharmacologic tests, making it possible to select cases harbouring a hormonally active tumour, such as the phaeochromocytoma Although paroxysmal hypertension is a characteristic feature of phaeochromocytomas, cases with mainly sustained hypertension are not uncommon (Fig 1) The diagnosis, based on clinical and laboratory tests, is generally accurate Cases exist, however, in which the laboratory data, probably as a consequence of *intermittent secretion* of pressure agents, do not support the clinical findings

The main task of the radiologist is therefore to localize the tumour and in some cases also to establish the diagnosis As aortography has become almost a routine procedure in the evaluation of arterial hypertension, and hormonal analyses are not always made, the phaeochromocytoma may be an unexpected radiologic finding Knowledge of the radiographic appearances of these tumours and of the hazards of the examinations is therefore of importance

Phaeochromocytomas arise from chromaffin tissue, mainly of the adrenal medulla and the paraganglia. About 90 per cent of all phaeochromocytomas occur in the adrenals and their proximity, the location next common is para-

Submitted for publication 23 January 1969

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Fig 2 Extra adrenal phaeochromocytoma fed by branches of the renal and inferior phrenic arteries (→) running at the periphery of the tumour which was situated medial to the right adrenal gland behind the vena cava The inferior phrenic artery (+→) filled via anastomosis from the inferior suprarenal artery The tumour could not be seen at exploration of the adrenal region the exploration was then extended to the retrocaval space

KOHLER & HOLSTI 1966, ROSSI et coll 1966, 1968, FRY et coll 1967, KAHN et coll 1967)

In our hospital, angiographies have been performed in all cases operated upon since 1950 Retroperitoneal pneumography has on the other hand only been carried out in about a third of the cases We have now reviewed all the angiographic examinations with a view to find out with what accuracy the phaeochromocytomas can be demonstrated and if they possess characteristic vascularity

*Material* This comprises 26 cases, 13 females and 13 males, with 27 growths (Fig 1), the mean age being 42 years (23 to 65 years) The symptoms in three women appeared during the last month of pregnancy and in two of these removal

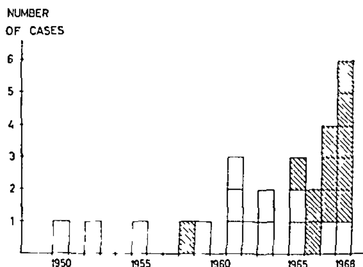



Fig 1 Phaeochromocytomas examined and operated on in the period 1950—1968 cases with paroxysmal signs (un filled columns) and cases with mainly sustained hypertension (hatched columns)

aortically along the sympathetic chain Rare sites, such as the urinary bladder (SIVAK 1961), the neck and even the skull, have been reported

The tumour occasionally appears in survey films as a soft tissue mass, or the diagnosis may be suggested by the deformation or displacement of a kidney Egg-shell calcifications have been reported to be almost specific (GRAINGER et coll 1967) In the overwhelming number of cases, however, the growth is demonstrated only by contrast medium techniques, such as angiography or retroperitoneal pneumography

The phaeochromocytomas are 'high-explosive neoplasms with a great tendency to release adrenalin or noradrenalin even by slight manipulations such as palpation of the abdomen or roentgen examinations Opinions vary regarding the most appropriate way to localize these growths Some authors, because of the risks of hypertensive crises, have suggested that specialized radiologic examinations should not be carried out, especially since in a number of cases (10 to 20 %) there are multiple phaeochromocytomas which, even if one of them has been localized, require extensive exploration (SJOERDSMA et coll 1966) Most authors are however of the opinion that the planning of surgical procedures is simplified if the tumour is demonstrated in one way or other Retroperitoneal pneumography has been the method most commonly used A number of papers illustrating the usefulness of angiography in the demonstration of phaeochromocytomas have been published in recent years (ELFVIN 1959, BOIJSEN et coll 1966,

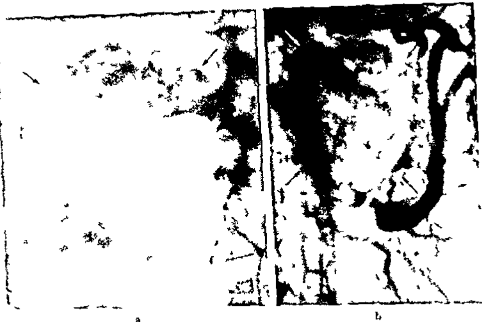



Fig 4 a) Right side phaeochromocytoma with faint accumulation of contrast medium and capsular veins (→) b) Left side phaeochromocytoma (→) in the late arterial phase of aortography The tumour vessels are arranged like irregular meshes of a net

examined by the translumbar approach and in the remaining cases the percutaneous retrograde transfemoral technique was used

Polythene catheters and a fairly small amount of a 50 % contrast medium were employed prior to 1959 (two cases in all) After 1959, the aortographies were performed with Ödman Ledin catheters or tip-occluded teflon catheters with side holes At least 50 ml of Urografin 60 % were administered with a Gidlund Elema injector Equipment for stereo-angiography was also utilized at this time, and in all cases, except those examined with the translumbar technique, an AOT film changer was used

The blood pressure was continuously recorded throughout the examinations, and vein cannulas were inserted for immediate regitine injections in case of imminent hypertensive crises The endocrinologist in charge of the case was always present during the procedure After 1964, all cases examined for phaeochromocytoma were prepared with phenoxy benzamine hydrochloride (dibenzyline) which, like regitine, is an alpha adrenergic blocking agent but has a more protracted effect than regitine Complications of any importance were not encountered neither before nor after the introduction of dibenzyline

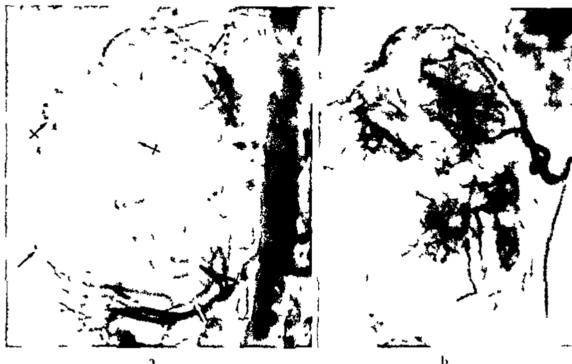


Fig 3 Aortography (a) and selective injection of a considerably widened inferior phrenic artery (b) in a case with large phaeochromocytoma (1 500 g) The feeding arteries (→) coursed at the periphery of the tumour and sent branches towards its centre There were vessels (→→) probably mainly veins that filled in the arterial phase

of the tumour was combined with Caesarean section In the third woman, with bilateral neoplasms, clinical and radiologic examinations and surgery were performed shortly after spontaneous delivery

All the tumours were situated in or contiguous to the adrenals, fifteen on the right and twelve on the left side One of the masses was entirely extra-adrenal, medial to the right gland and retrocaval (Fig 2) Two of the others were separated from the adrenal glands but connected to them by thin fibrous strands Considerable variations in size and weight of the tumours were recorded, the weight ranging from 11 to 1 500 grams No correlation could be established between the size of the tumour and the hormonal activity

Microscopy disclosed typical features of benign phaeochromocytomas Different degrees of degenerative changes with necrosis and cysts were the rule

*Angiographic technique* As the study extends over a period as long as 18 years, the quality of the angiograms differed in the early and the late cases Contrast media, as well as the technique of their injection, film changers and roentgen tubes have improved considerably during this time Two of the early cases were



a



b



c

to the upper renal pole (↔) could be demonstrated

provocative histamine tes a blood sample from the left renal vein indicated a marked increase in noradrenalin

The material includes two cases with false positive diagnoses In both, a left-side growth, in addition to the correctly diagnosed tumour on the right side, was considered probable In one of the cases, retroperitoneal pneumography revealed a mass close to the left upper renal pole, probably explained by marked irregular-

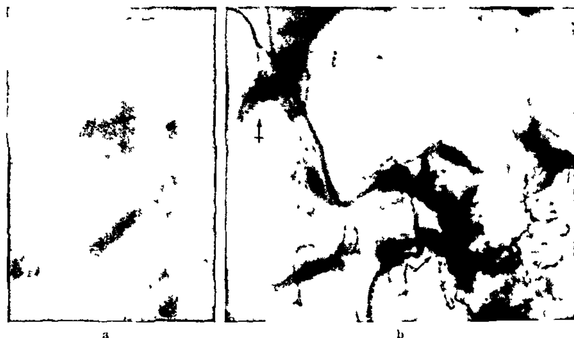



Fig 5 a) Highly vascularized right side phaeochromocytoma homogenous accumulation of contrast medium in the venous phase b) The complex arterial supply of the adrenals is illustrated by a left side phaeochromocytoma supplied by branches from the first part of the right inferior phrenic artery (→) which arose from the left side of the aorta There were branches also to the normal right adrenal gland (↔)

## Results

Eight of the twenty-seven tumours were not diagnosed preoperatively by angiography Two of these had slight but significant angiographic changes that were overlooked In the remaining six cases, angiographic localization was not possible even on retrospective viewing In three of these cases, belonging to the early part of the material, the angiographic examinations were incomplete The tumour in these cases and in an additional case was demonstrated by retroperitoneal pneumography Thus two angiographically negative cases remain One was of a pregnant woman in whom exploration combined with Caesarean section was made without further diagnostic procedures The tumour was small and situated totally within the adrenal gland, visible only after division of the gland The tumour was small also in the second case, its diameter being about 2 cm, it lay in the angle between the aorta and the left renal artery and arose from an ectopic adrenal gland Retroperitoneal pneumography suggested a normal adrenal gland and no mass was seen Selective adrenal phlebography was attempted but without success Blood specimens were taken during the examination After a



Fig 6 Left side phaeochromocytoma situated almost totally in front of the upper renal pole At aortography the tumour was difficult to identify in the arterial phase (a) because of superimposition of renal vessels, in the venous phase (b) the tumour was delineated by capsular veins (→) *At retroperitoneal* pneumography (lateral tomogram) (c) the relation of the tumour (→) to the upper renal pole (↔) *could be* demonstrated

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Fig 8 Left side phaeochromocytoma visible only at selective angiography a) Aortography b) and c) Selective injection of the renal artery There are tumour vessels (→) only within a small area in (b) In the venous phase (c) a capsular vein (⟶) is clearly seen

that no vascular pattern could be identified These growths appeared in a late phase as homogenous accumulations of contrast medium (Fig 5a) In a few cases the neoplasms were less vascularized having a conglomerate of minute tortuous arteries within a small area only (Fig 8b) A few wide irregular vessels mainly resembling veins were observed in the arterial phase in several cases especially in those with large tumours (Fig 3a) Less vascularized areas were seen in all growths rich in vessels probably due to the aforementioned degenerative changes with necrosis and cysts.

## Discussion

Rossi Young & Panke (1968) stated angiography is an effective method for the localization of phaeochromocytomas They based this statement on 99 cases, twelve of their own — up to now the largest published number of cases examined angiographically — and the remainder collected from the literature The same conclusion may be drawn from the present material which comprises 27 neoplasms most of which were demonstrated at angiography The angiographic diagnosis is in many cases difficult especially in small tumours the main cause being the complex and variable arterial supply of the adrenal glands (Merklin & Michels 1958) The supply is derived from many small arteries of different origin usually the renal arteries the aorta and the inferior phrenic arteries the

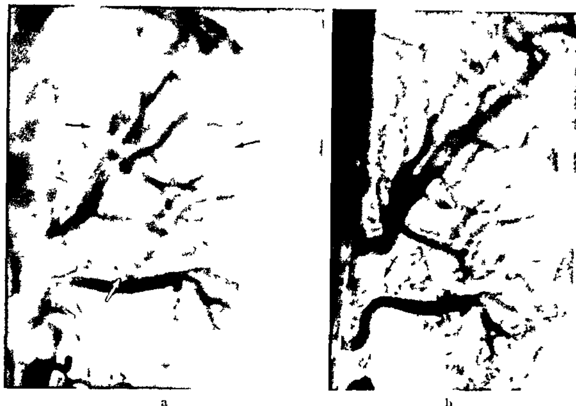



Fig 7 Large left side phaeochromocytoma in front of the kidney a) The tumour (→) was partly superimposed by renal vessels b) A small tortuous feeding artery (↔) coming directly from the aorta enabled the diagnosis to be made (subtraction film)

ity of the renal pole, with deep retractions which most likely were due to pyelonephritic lesions In the second case, a fairly large branch from the left renal artery suggested a hypertrophic suprarenal artery Definite tumour vessels were not seen No gas study was performed

The angiographic appearances of the phaeochromocytomas were fairly characteristic, although not uniform The feeding arteries in practically all the cases followed the periphery of the neoplasm (Figs 2 and 3) A characteristic feature of these arteries was that they maintained almost the same calibre around the tumour Wide veins, probably capsular veins, encircling the mass (Figs 4a 6b and 8c), was a constant finding Four different types of vascular pattern within the tumours may be recognized in the material

In some cases, branches from the peripheral arteries, resembling the spokes of a wheel, converged towards the centre of the tumour (Fig 3) These branches in other cases had a reticulated arrangement like irregular meshes of a net (Fig 4b) The arteries, especially in small tumours, were sometimes so abundant




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in phaeochromocytomas



Fig 10 Adrenal carcinoma with Cushing s syndrome There are feeding arteries at the periphery of the tumour and irregular vessels in the medial part of the otherwise poorly vascularized growth

other possible supplementary sources being the lumbar, the ureteric and the gonadal arteries The inferior phrenic artery may arise from the aorta, from the coeliac artery or one of its branches or from the renal or lumbar arteries (Fig 5b) To ensure demonstration of all the suprarenal arteries the deposition of the contrast medium must be made in the aorta, above the origin of the coeliac artery Superimposition of a great number of coeliac and mesenteric branches makes identification of the very narrow suprarenal arteries difficult

The tumours on the right side are most often situated above the upper renal pole, usually deforming it and displacing the kidney in a typical way The growths may, however, extend caudally in front of and medial to the kidney, between it and the vena cava On the left side the tumours are usually located partly or entirely in front of the upper renal pole (Fig 6) The neoplasm in one of the cases lay as low as the hilum of the kidney (Fig 7) Superimposition in these cases of not only coeliac and mesenteric but also of renal branches makes the angiographic diagnosis even more difficult Some of the problems caused by superimposition of arterial branches may be overcome by angiography in different projections The blocking treatment with dibenzyline has encouraged us to perform repeated injections into the aorta as well as selective angiographies



Fig 11 Selective angiography of the ren l [illegible]

plasm

With high quality films obtained in different projections most phaeochromocytomas can usually be demonstrated at aortography In one of the cases in which aortography as well as selective angiography were performed (Fig 8), the tumour could be demonstrated only in the selective examination Obvious changes in several other cases appeared only after selective injection even though they could be detected in retrospect in the aortograms. We therefore feel that the examination should proceed with selective *angiography* whether or not a possible lesion is found The suprarenal arteries cannot be catheterized unless pathologically widened By selective suprarenal arteriography is meant contrast injection into one of the large arteries from which the suprarenal arteries arise the renal the inferior phrenic and the *coeliac* arteries The suprarenal arteries that are most easily examined are those arising from the renal arteries Catheters with side holes are employed to ensure filling of the inferior suprarenal arteries

which often spring from the very first portion of the renal artery (Figs 2 and 8b) The inferior phrenic artery with the superior suprarenal branches, mostly arising directly from the aorta, can often be catheterized (Figs 3b and 5b) If a tumour is demonstrated at aortography, and the adrenal region of the opposite side cannot be evaluated with certainty, selective examination should be made on that side since the phaeochromocytomas may be bilateral Even if no tumour can be observed, in spite of careful examinations, a small avascular mass or one outside the suprarenals may still be present

Retroperitoneal pneumography was performed in those cases in which no neoplasm could be demonstrated at angiography One small tumour, not visible at angiography, could thus be demonstrated The accuracy of the two methods cannot be compared since retroperitoneal pneumography was not performed in all cases Retroperitoneal pneumography does not reveal the nature and origin of a new growth and normal structures may be mistaken for pathologic masses It is not always possible to direct the gas to the suprarenal areas, probably because of retroperitoneal adhesions secondary to haemorrhages around highly vascularized tumours An advantage of angiography is the possibility of demonstrating neoplasms in regions outside the adrenal glands (Fig 2)

Tumours within or close to the right adrenal gland sometimes make impressions in the inferior vena cava and may be demonstrated by inferior vena cavography (LUND et coll 1960) Blood samples for determination of catecholamines should be obtained at different levels during the procedure, preferably before and after provocative histamine tests

The angiographic appearances of phaeochromocytomas were discussed by BOIJSEN et coll (1966) and ROSSI et coll (1966, 1968) ROSSI has stated that benign phaeochromocytomas lead to typical angiographic appearances, with hypertrophy of the suprarenal arteries and a finely reticulated network of small arteries in the early arterial phase An homogeneous accumulation of contrast medium, in which there may be zones of decreased vascularity, appears in the capillary phase This is in general agreement with the present findings We would however like to stress that the vascularity varies considerably in many cases there is no accumulation of contrast medium within the tumour but the course of the feeding arteries around the periphery of the tumour is typical and wide capsular veins are rarely absent LAGERGREN (1967) examined six cases of phaeochromocytomas by microangiography He encountered hypervascularity in only one case and was of the opinion that the vascular pattern in the other cases could not be distinguished from that of adenomas, neither by clinical angiography nor by microangiography

The angiographic appearances of the phaeochromocytomas in the present material were compared with those of other adrenal growths, eight adenomas and

nine carcinomas It is true that all adrenal tumours have many characteristics in common such as supply arteries following the periphery, but the vascularity of benign phaeochromocytomas was different from that of other adrenal neoplasms The vessels in the small adenomas were narrow and irregular with no characteristic pattern (Fig 9) Large adenomas as well as carcinomas were fairly poor in vessels but with small areas of irregular tumour vessels (Fig 10) Wide irregular veins and venous lakes, irregularly scattered in the growths, was a characteristic finding (Fig 11) The problem of the differential diagnosis is however of minor importance since the nature of adrenal neoplasms can be determined by hormonal analysis

## Conclusions

It is usually possible to verify the diagnosis and locate phaeochromocytomas with arteriography Small tumours, especially if poorly vascularized or situated totally within the adrenal glands, may be impossible to demonstrate The arteriographic diagnosis is often difficult and requires, besides experience, a proper technique with high film quality, several projections and selective injections

## Acknowledgements

The authors wish to thank Docent B Sjogren and Dr L. Ohlsson of the Department of Endocrinology who made the clinical examinations, and Docent H Ekman of the Department of Urology who operated on the cases

## SUMMARY

The arteriographic appearances of phaeochromocytomas based on the examinations of 26 cases with 27 tumours are discussed All the growths were benign and situated in or contiguous to the adrenal glands The vascularity which is fairly characteristic, is compared to that of other adrenal tumours

## ZUSAMMENFASSUNG

Die arteriographischen Befunde wurden in 26 *Fällen mit* 27 Phaeochromocytomen analysiert Alle Geschwulste waren gutartig und entweder innerhalb oder wenigstens nahe den Nebennieren lokalisiert Das Gefassbild das ziemlich charakteristisch ist, wurde mit dem anderer Nebennierentumoren verglichen

## RÉSUMÉ

Les auteurs examinent les signes arteriographiques des pheochromocytomes en se basant sur l examen de 26 cas presentant 27 tumeurs Toutes ces tumeurs étaient benignes et etaient situees dans les glandes surrenales ou leurs etaient contigues Ils comparent leur vascularisation qui est assez caractéristique a *celle d autres* tumeurs surrenales

which often spring from the very first portion of the renal artery (Figs 2 and 8b) The inferior phrenic artery with the superior suprarenal branches, mostly arising directly from the aorta, can often be catheterized (Figs 3b and 5b) If a tumour is demonstrated at aortography, and the adrenal region of the opposite side cannot be evaluated with certainty, selective examination should be made on that side since the phaeochromocytomas may be bilateral Even if no tumour can be observed, in spite of careful examinations, a small avascular mass or one outside the suprarenals may still be present

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FROM THE CARDIORESPIRATORY RESEARCH UNIT AND THE DEPARTMENTS OF PATHOLOGY AND ROENTGENOLOGY, UNIVERSITY OF TURKU, FINLAND

# MICROANGIOGRAPHY OF THE RENAL VESSELS IN RABBIT

## Comparison of different methods

by

HEIKKI WENDELIN and ILMARI LINDGREN

The aim in renal microangiography is to obtain complete contrast filling of certain vessels The results are influenced by various inter related factors, which have been widely discussed in the literature (BARCLAY 1951, BELLMAN 1953, HERZOG 1957, and RUBIN 1964) Most authors agree that the infusion pressure should be close to the physiologic blood pressure limits that correspond to the vessel to be infused The injection time may vary from a few minutes to several hours (LJUNGQVIST 1963)

The usual contrast media have recently been replaced by suspensions of $BaSO_4$ in various concentrations This is a particulate medium and technical aspects in the preparation of the suspension must therefore be taken into account (KORMANO 1967) A similar type of particulate contrast medium of high density has recently been introduced, it has the advantage of being brightly colo[illegible]

[illegible] heavy metal salts The particle size is said to be less than 1 micron. (The *precise nature* of Chromopaque has not been disclosed )

Submitted for publication 7 January 1969

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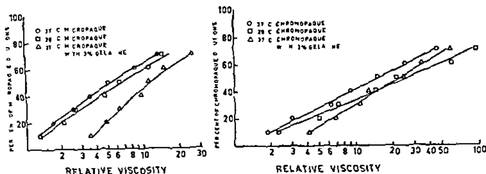



Fig 1 The relative viscosity values of Micropaque dilutions (a) and of Chromapaque dilutions (b) at different temperatures and percentages (the viscosity of distilled water taken as 1)

nulated with a polythene tube at laparotomy and the renal vein cut The animals were heparinized (dose 5 000 I U ) before anesthetization

Specially prepared 250 ml bottles were used (LJUNGQVIST 1963) Because the contrast medium is particulate, the bottle was placed on a magnetic stirrer provided with a thermoregulator The 100 mg Hg infusion pressure was kept constant with a liquid air flask and controlled with a Hg manometer, the infusion time was one hour, after which the flow ceased

The contrast medium suspensions were diluted with physiologic saline to the required percentages In some cases when the temperature was 37° C the contrast media contained 3 % gelatine The data of the experiments are given in a Table The relative viscosity of the contrast media was measured with an Ostwald viscometer (BULL 1964)

The infusion was made at two different body temperatures + 20° C and + 37° C The respective temperatures of the contrast media were kept the same The infusion at + 37° C was made while the animal was under anesthesia and until the animal died during the procedure The infusion at + 20° C was applied to fresh post mortem material Furthermore, 4 kidneys were deep-frozen to — 25° C and stored for several days, after which they were rewarmed to + 20° C and infused with Chromapaque 10 % at + 20° C This was done in order to study the vascular filling of the deep-frozen stored organs

At least 2 kidneys were used in each experiment After infusion the renal vessels were l[illegible]

of the [illegible]

formal [illegible] days after complete fixation the kidneys were cut frontally in series of 2 mm thick slices and radiographed for preliminary orientation on Kodalith Contact Photomechanical Film A Machlett AEG-50 roentgen

**Table**

*Results obtained in the different experimental conditions*

| Contrast medium | | | | Filling degrees of the renal vasculature of rabbit | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Suspension | Concentration % | Temperature C° | Relat viscosity | Arcuate artery o 100 μ | Interlobular artery o 50 μ | Afferent arteriole o 30 μ | Arteriole in glomerulus o 10 μ | Direct arteriole o 10 7 μ | Efferent arteriole o 7—5 μ |
| M | 10 | 20 | 1 3 | +++ | +++ | +++ | +++ | ++ | ++ |
| M | 10 | 37 | 1 2 | +++ | +++ | +++ | +++ | +++ | +++ |
| M with gelatine 3 % | 10 | 37 | 3 7 | +++ | +++ | +++ | +++ | +++ | +++ |
| M | 40 | 20 | 4 3 | +++ | +++ | 0 | 0 | 0 | 0 |
| M | 40 | 37 | 3 6 | +++ | +++ | +++ | ++ | + | 0 |
| M with gelatine 3 % | 40 | 37 | 8 5 | +++ | +++ | +++ | +++ | ++ | + |
| C | 10 | 20 | 2 3 | +++ | +++ | +++ | +++ | ++ | + |
| C | 10 | 37 | 2 0 | +++ | +++ | +++ | +++ | +++ | +++ |
| C with gelatine 3 % | 10 | 37 | 4 1 | +++ | +++ | +++ | +++ | +++ | +++ |
| C | 40 | 20 | 15 | +++ | +++ | ++ | + | 0 | 0 |
| C | 40 | 37 | 9 0 | +++ | +++ | +++ | ++ | + | 0 |
| C with gelatine 3 % | 40 | 37 | 15 | +++ | +++ | ++ | + | 0 | 0 |

M — Micropaque C — Chromopaque +++ indicates complete, ++ moderate + *sparse* but detectable and 0 no filling of vessels

The purpose of the present investigation has been to compare a *BaSO₄* suspension (Micropaque, Damancy & Co Ltd) and Chromopaque under certain physical conditions The infusion pressure and time were kept constant The variables studied were the viscosity, temperature and concentration of the contrast media The rabbit kidney was chosen as a test organ because its vasculature has been well studied and the different degrees of its vascular filling can therefore readily be distinguished (RUBIN 1964, LJUNGQVIST & LAGERGREN 1962)

*Material and Methods* The material consisted of 27 adult rabbits of both sexes weighing between 2 7 and 3 4 kg The animals were anesthetized and killed with pentobarbitone sodium (Nembutal, Abbot) The renal artery was can-




Fig 3 Two microradiograms demonstrating the different degrees of renal vascular filling a) Chromopaque 10 % at + 37° C Complete filling as far as the efferent arterioles b) Chromopaque 40 % at + 37° C Complete filling of afferent arterioles and partial filling of the glomeruli The microradiograms are reproduced from the original ones × 100

tube with 1 5 mm focus and equipped with a 1 5 mm thick beryllium window was employed, this was run at 30 kV The slices were placed on a 0 5 mm plastic film which was in contact with the photographic material The film focus distance was 1 meter

After the preliminary examination, one slice was chosen for embedding in paraffin beeswax (4/1), and 150-micra sections were cut for contact microradiography The same tube and kV were used, but the focus-film distance was decreased to 0 5 meter and the photographic material changed to Kodak Spectroscopic Plate 649 E or to Kodak Maximum Resolution Plate

The different parts of the renal arterial and capillary pattern were identified in the micrograms and their minimum diameter was measured microscopically (see Table) The degree of contrast filling was also verified from an ordinary histologic section made from the original microradiographed section, 5 to 7 micra paraffin sections were taken and stained by conventional methods.

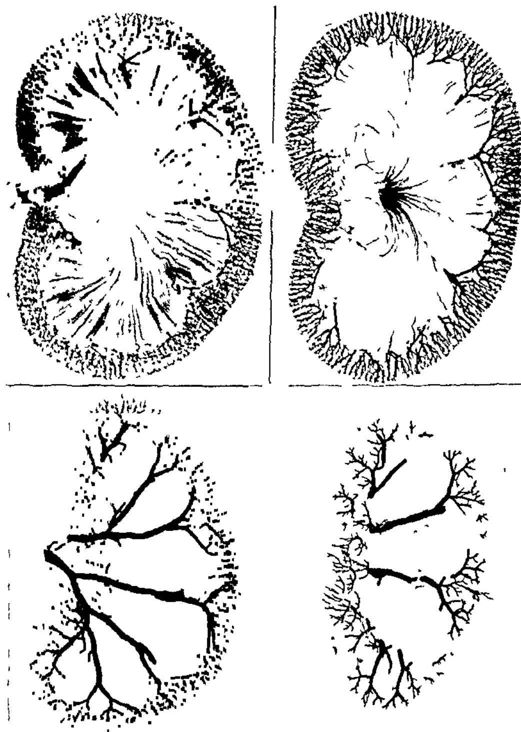


Fig 2 Different degrees of filling of the renal arterial vasculature of the rabbit *Upper left* Chromopaque 10 % at 37° C Complete filling of arterial capillary vasculature *Upper right* Micropaque 10 % at + 20° C Complete filling of the glomerular capillaries, moderate filling of the smaller capillaries *Lower left* Micropaque 40 % at + 37° C Complete filling only as far as the afferent arterioles *Lower right* Micropaque 40 % at + 20° C Complete filling only as far as the interlobular arteries




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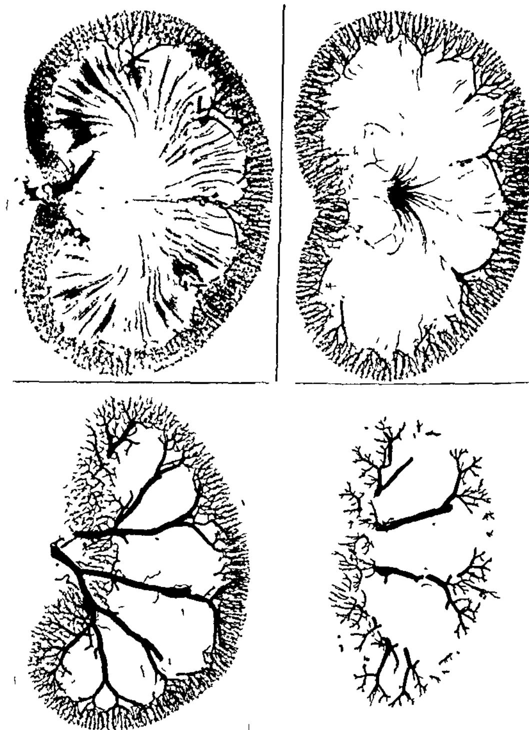


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Table are presented in Fig 3 Chromopaque has also other characteristics it can be more easily detected in the histologic specimen with all the usual staining methods (Fig 4) and it leads to better radiographic contrast

The degree of vascular filling varied in kidneys which were deep-frozen, stored and rewarmed to + 20° C, and then infused with Chromopaque 10 % There was complete filling of the afferent arteries but moderate or sparse filling of the smaller vessels No filling of the efferent arterioles could be detected

## Discussion

The best way to fill the vessels to demonstrate the capillary level is to keep the temperature of the kidney and the contrast medium within physiologic limits This can be achieved when the animal is anesthetized and dies during the infusion Furthermore, the relative viscosity of the contrast medium should be about the same as that of the blood of the living animal One would think that under such conditions some kind of trauma or shock would alter the vascular pattern of the kidney (BARCLAY 1951) but no such phenomenon was observed, and all the vessels as far as the efferent arterioles were in fact filled with the contrast medium

The investigation indicates that the demonstration of vessels of a certain diameter may be achieved by choosing a suitable viscosity (HARRISON & HOEY 1960) of the contrast medium to be infused (see Table) The addition of gelatine has the advantage of making the medium thicken in the vessels so that it does not leak out during the fixation of the organ (RUBIN 1964) Gelatine can however not be used at temperatures lower than + 37° C because of its coagulation tendency, at this temperature however and in low concentrations of the contrast medium, the addition of gelatine seems to produce good filling of the capillaries

No filling of the venous side was seen in this study This may be due to the fact that the solvent diffuses out of the capillaries and causes the contrast medium to be more concentrated, filling of the venous side cannot then occur For the opposite reason it is possible to obtain good contrast with a lower concentration in the smaller vessels

Comparison of the two contrast media discloses that Chromopaque has the advantage of producing a better radiographic contrast and in histologic sections can be seen more easily than Micropaque Contrast infusion for purposes of microangiography are often performed on deep-frozen stored material The present results indicate however that the filling of the capillaries is then not so good as when the material is fresh



a b

Fig 4 Histologic details from two renal capillaries in the rabbit completely filled with contrast media Van Gieson stain Reproduced from the original × 100 a) Chromopaque 10 % at + 37° C The filling at the capillary level is clearly visible even in the histologic section b) Micropaque 10 % at + 37° C Poor contrast filling

## Results

The results are presented in the Table The relative viscosity values at different temperatures and concentrations of the two contrast media are given in Fig 1 The relative viscosity of the blood was 4 8 at 20° C and 3 8 at 37° C

As the Table indicates, complete filling at the capillary level could be obtained *when the viscosity of the contrast medium was the* same or *less than the viscosity* of the blood When the viscosity was increased, the smaller vessels were not filled However, better filling was obtained at + 37° C as compared to + 20° C, although at these temperatures the viscosity values are quite close to each other (exception Chromopaque 40 %) The addition of 3 % gelatine does not impair the filling of vessels if the relative viscosity of the contrast medium remains under 10 Examples of different grades of filling are given in Fig 2 In none of the specimens could any filling of the venous side be seen

The microradiograms indicated that the best filling to the capillary level was obtained at + 37° C both with Micropaque 10 % and Chromopaque 10 % suspensions with or without gelatine 3 % Examples of the criteria used for the

FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY (DIRECTOR U. RUDHE) THE PEDIATRIC CLINIC, AND PEDIATRIC PATHOLOGY (DIRECTOR B. IVEMARK), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

# ATYPICAL ROENTGEN APPEARANCES OF THE LUNG IN HYALINE MEMBRANE DISEASE OF THE NEWBORN

by

ULF RUDHE, FREDERICK R. MARGOLIN and BENGT ROBERTSON

Diffuse symmetric pulmonary reticulogranularity has received considerable emphasis in roentgenologic descriptions of hyaline membrane disease of the neonatal lung. The atypical roentgen features of this disease have been only briefly mentioned (SCHULTZE 1958, CURRARINO & SILVERMAN 1957, AVERY 1968, PETERSON & PENDLETON 1955, and SINGLETON 1967). Little attention appears to have been given to the unevenly distributed or asymmetric pulmonary infiltrates seen in chest roentgenograms, especially during the first few hours of life.

We have reviewed the chest roentgenograms of 66 newborns in whom a clinical or pathologic diagnosis of hyaline membrane disease was made during the period 1959—1967 and demonstrated atypical roentgen features in twelve, post mortem examination was performed in eight of these infants who died within 144 hours post partum. (No histologic data were available for the four survivors.)

Fifty five additional infants with classical diffuse symmetric pulmonary reticulogranularity (Fig. 1) were chosen to represent the typical roentgenographic manifestations of hyaline membrane disease. The histologic specimens available

Submitted for publication 7 January 1969.

## Acknowledgements

This investigation was supported by the P O Klingendahl Foundation for Radiologic Research and by the Sigrid Juselius Foundation



## SUMMARY

Two contrast media Micropaque and Chromopaque used in microangiography were studied in order to determine the effect of the temperature and concentration on the filling of the renal vasculature in the adult rabbit Complete capillary contrast filling was obtained only when the concentration of the medium was 10 % and the infusion was made at + 37° C when the anesthetized animal died during the procedure Chromopaque appeared to be more satisfactory generally than Micropaque

## ZUSAMMENFASSUNG

Zwei Kontrastmittel Micropaque und Chromopaque die fur Mikroangiographie angewendet werden wurden gepruft um den Einfluss von Temperatur und Konzentration auf die Darstellung der Nierengefasse der erwachsenen Kaninchen zu studieren Komplette Kapillarfullung wurde nur bei einer 10 %iger Konzentration des Kontrastmittels erreicht wenn die Infusion bei einer Temperatur von 37° C stattfand und das anasthesierte Tier wahrend des Experimentes starb Chromopaque scheint im allgemeinen befriedigender als Micropaque zu sein

## RÉSUMÉ

Deux moyens de contraste Micropaque et Chromopaque utilises en microangiographie ont été étudies pour déterminer l effet de la température et de leur concentration sur l injection des vaisseaux renaux du lapin adulte On n obtient une injection capillaire complete que quand la concentration de ces moyens de contraste est de 10 % quand l injection est faite a 37° C et quand l animal anesthésie meurt au cours de l injection D une façon generale le Chromopaque parait plus satisfaisant que le Micropaque


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Fig 2 Massive atelectases of reticulogranular type in right lower lobe and delicate disseminated atelectases in the remainder of the lungs in 1 day old infant who was a survivor of the respiratory distress syndrome

cases The reticulogranularity was nevertheless diffuse in the roentgenograms Evenly distributed atelectases throughout the lungs were revealed histologically in all the cases

Intra alveolar edema, interstitial and intra alveolar hemorrhage and inflammation were seen in one or more lobes in twenty one of the twenty-three cases. The intensity of these changes was assessed according to the criteria given by ROBERTSON (1963) Severe hemorrhage (grade III) was encountered only among subjects living 3 to 5 days, while grades 0, I, and II occurred from the age of 1 to 2 days, and exceptionally at 5 to 6 days Inflammation was observed in six cases only, four of which had grade I, one grade II and one grade III

No lesion could be differentiated in the roentgenograms which presented evidence of typical diffuse bilateral atelectases of a reticulogranular type, except in one instance of grade III inflammation The latter, which initially had the classical roentgen appearances of hyaline membrane disease, presented a distorted pattern compatible with complicating pneumonia on a second roentgen examination It was also noteworthy that one of the cases with associated grade III hemorrhage involving all lobes had a characteristic diffuse reticulogranular pattern in the lung in serial films, these included post mortem roentgenograms It appears that histologically massive pulmonary hemorrhage may be less likely to alter the characteristic reticulogranular pattern of hyaline membrane disease than inflammation of comparable severity



Fig 1 Typical roentgen features with regularly disseminated atelectases of reticulogranular type in a premature infant with hyaline membrane disease Hyaline membranes and diffuse atelectases were present post mortem in all lobes of the lungs

in thirty-three of these served as controls for a comparison of the roentgenologic and histologic findings with the atypical cases under review

*Methods* Post-mortem histologic examination of the lungs was carried out in the eight fatal cases with 'atypical roentgenologic features, as well as in the thirty-three fatal cases of the control series Specimens from all lobes were examined in six of the eight atypical cases and in twenty-three of the thirty three controls Only 4 sections from different lobes were available in two atypical cases, and from 1 to 4 sections were studied in ten control cases

Large frontal sections of the whole lungs were examined in a few instances This greatly facilitated the spatial correlation of the roentgenologic and histologic findings (see Fig 5)

## Results

*Control series* All the thirty-three cases of roentgenographically classical diffuse bilateral pulmonary reticulogranularity were proved to have hyaline membrane disease on histologic examination of the lungs Hyaline membranes were uniformly distributed throughout the lungs in eighteen of the twenty-three cases in whom specimens from all lobes were available A discrepancy between the roentgenologic and histologic findings was noted in five cases Hyaline membranes were absent in one lobe, i e respectively the right upper, the left upper and the left lower lobe in three of these, and in the right middle lobe in the two remaining



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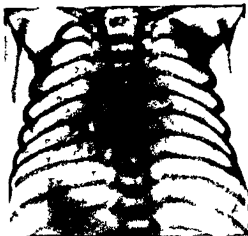


Fig 4 Reticulogranularity most accentuated in the central portions of the lungs and intra alveolar edema and hemorrhage

being more prominent in the lower lobes in three additional cases Diffuse distribution of hyaline membranes was present in the remaining two cases of this group

Irregularly distributed areas of intra alveolar and interstitial hemorrhage were noted sometimes associated with intra alveolar edema in five of these eight cases Edema alone was found in one child Pneumonia was recorded in four and was the dominant microscopic finding in two of them The time of appearance of the pneumonia could not be assessed Signs of aspiration were inappreciable

Pulmonary reticulogranularity was common to all the twelve atypical cases although it was asymmetric and irregularly distributed The changes predominated unilaterally in several cases and in the three survivors disproportionately involved one lobe (Fig 2)

The distribution of atelectases was roentgenographically more diffuse but spared the upper lobes (Fig 3) or the right middle lobe this correlated with the histologic sections that demonstrated these lobes to be free of membranes. Another characteristic was the predominantly central distribution of reticulogranularity leaving the peripheral parts of the lungs uninvolved on one or both sides (Fig 4)

The degree of intra alveolar or interstitial hemorrhage observed at autopsy in five instances ranged from grade 0 to grade II in four cases and was grade III in the remaining case Since lesions of comparable degree of severity failed to alter the roentgenographic characteristics of generalized hyaline membrane disease in the control series it was concluded that hemorrhage did not contribute significantly to the production of an asymmetric reticulogranular pattern

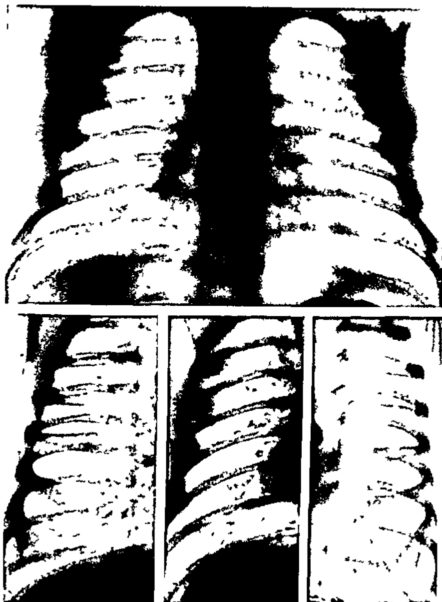


Fig 3 Typical reticulogranular pattern of diffuse atelectases in lower and middle lobes normal findings in the upper lobes in 1 day old infant progressive clinical deterioration and death at 3 days Histologic examination hyaline membranes in lower and right middle lobe none in upper lobes complicating moderate to marked intra alveolar hemorrhage and inflammation in upper and middle lobes (not visible in the 1 day roentgenogram)

*Atypical disease* Among the eight cases with roentgenologically atypical disease, one or two lobes were free of hyaline membranes on histologic examination in three instances Membranes were present in all lobes, but unequally distributed,

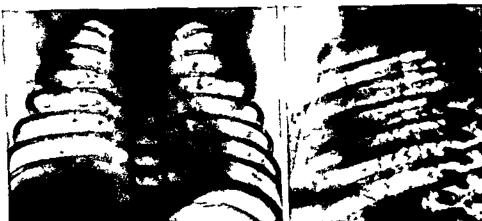


Fig 6 Scattered small infiltrates in both lungs interspersed with generalized reticulogranularity in 1-day-old infant Histologic examination hyaline membranes of varying thickness in all lobes, complicating widespread areas of pneumonia

Variations in the typical appearances of the disease in one or more roentgenograms obtained in the course of the syndrome were noted in twelve cases This retrospective study did not permit of a sufficiently close correlation of the histologic findings with the maximal asymmetry of the roentgenologic changes Nevertheless, the evidence suggests that these atypical roentgen findings in the neonatal lung sometimes reflect the existence of a non generalized form of the disease, in which membranes are absent in one or more lobes Atypical roentgen appearances may also result from the association of inflammation with the hyaline membrane lesion By contrast, edema and hemorrhage, even when severe, do not seem to modify the classic roentgenologic features of the disease

BLYSTAD et coll (1951) reported a series of 94 necropsies in infants with hyaline membranes who died between 1 hour and 5 days of age and in whom an associated pneumonia occurred in 29 8 % and pulmonary hemorrhage in 45 % LANDING (1957), in a statistical study of 125 consecutive neonatal necropsies, found a definite association between pulmonary hemorrhage and pneumonia. He stated, however, that hyaline membranes were not significantly associated with either of these lesions According to POTTER (1952), inflammation was usually noted in the lungs of infants with hyaline membrane disease who died after 48 hours ROBERTSON (1963), in a histologic study of the relationship between pulmonary hyaline membranes and co-existing pulmonary lesions in the immediate neonatal period, reported that the incidence of complicating pneumonia and hemorrhage increased with postnatal age Significant co-existing

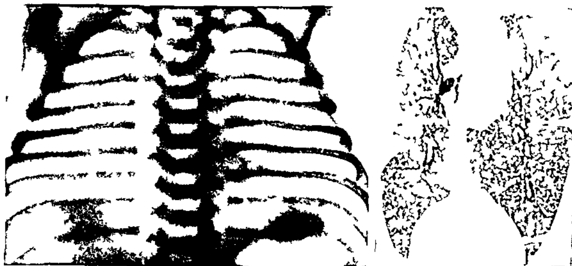


Fig 5 Disseminated atelectases of reticulogranular type and areas of consolidation in the lower lobes, particularly the posterobasal segments which project through the diaphragm in 1 day old infant who died at 2 days Histologic examination hyaline membranes present in all lobes accentuated in the lower lobes Intra alveolar hemorrhage at apex of left upper lobe and pneumonic consolidation of parts of lower lobes The frontal sections through the lungs show disseminated atelectases and areas of hemorrhage and pneumonia

Post-mortem evidence of pneumonia, assessed as grade III, was noted in four instances, and was of lobar distribution in two cases (Fig 5) Multiple abscesses were scattered throughout the lungs of an additional newborn with sepsis and diabetic embryopathy (Fig 6)

*An initially asymmetric and uneven distribution of reticulogranularity* progressed to a more typically diffuse and symmetric appearance in three cases (Fig 7) An asymmetric parenchymal process persisted or progressed as a result of sepsis and lung abscesses in one of these

## Discussion

Collapsed alveoli, aerated terminal bronchioles, alveolar ducts, and hyaline membranes are typical microscopic findings in the lungs of infants dying of the respiratory distress syndrome ROSENGREN (1967) has demonstrated in animal experiments that it is this histologic pattern that produces the reticulogranularity which radiographically is so characteristic of this disease Since it is apparent that reticulogranularity relates to atelectases rather than to the membranes themselves this fact may explain why *the diffuse atelectases and non-generalized membranes* that were observed in five cases in the control series still had reticulogranularity throughout the lungs



Fig 8 Almost airless lungs with loss of structural details at 6 hours Histologic examination signs of massive intra uterine aspiration with areas of hyaline membranes in process of formation, multiple small interstitial hemorrhages

with the aspiration syndrome were examined at necropsy but in only one instance were hyaline membranes found SINGLETON (1967) has referred to the relatively frequent occurrence of hyaline membranes in the lungs of infants who die of the aspiration syndrome AVERY (1968), however, regarded this com- [illegible]

[illegible] the infant, whereas the aspiration syndrome is more prevalent in the postmature infant However, aspiration atelectases, when present, may mask the reticulogranularity characteristic of hyaline membrane disease This is particularly evident with massive aspiration when the thorax may be non aerated, simulating the changes of severe hyaline membrane disease (Fig 8) As ROSENGREN (1967) stated, the reticulogranular pattern depends on at least partial alveolar aeration Thus, reliable roentgenologic differentiation between these two processes is not possible in airless lungs

The unilateral or predominantly lobar distribution of hyaline membrane disease has not been widely appreciated MOLZ (1967) reported a case of hyaline membranes involving only one lung Isolated lobar distribution of hyaline membranes was noted at necropsy in five cases with typical roentgen changes and in four of the cases with atypical roentgen findings in the present study, roentgeno-

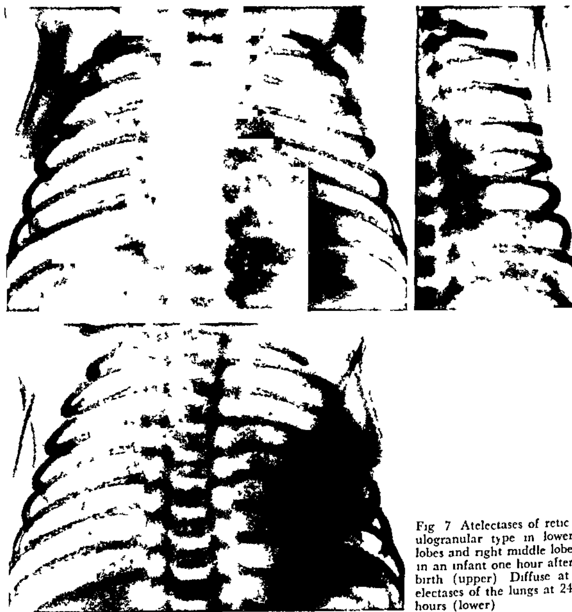


Fig 7 Atelectases of reticulogranular type in lower lobes and right middle lobe in an infant one hour after birth (upper) Diffuse atelectases of the lungs at 24 hours (lower)

pulmonary lesions, such as pneumonia or hemorrhage, were demonstrated histologically in one or several lobes of the lungs in six of the roentgenologically atypical, and in twenty-one of the control cases, in the present material

PETERSON & PENDLETON (1955) analyzed 104 neonatal roentgenograms that revealed a diffuse reticular pattern in the lungs and an additional 34 films with a coarse, irregular texture of atelectasis The former represented hyaline membrane disease and the latter the aspiration syndrome, only in one case were the roentgen features of both diseases combined The lungs in four of their cases

of the twenty three control cases was insufficient to produce a perceptible roentgenographic alteration in the reticulogranular pattern or it occurred preterminally and was not recorded in the last film obtained

Signs of aspiration were not observed Concurrent pneumothorax and resolution of the hyaline membrane process are conditions which should be considered when evaluating atypical reticulogranularity in the neonatal chest roentgenogram

## Acknowledgement

Financial support from the Swedish National Association against Heart and Lung Disease is gratefully acknowledged This study was conducted when F R M., Research Fellow in Diagnostic Radiology National Institutes of Health U S.A was on leave from the Department of Radiology, University of California School of Medicine San Francisco

## SUMMARY

The atypical roentgenologic appearances of the lungs of 12 neonates with the respiratory distress syndrome are analyzed and in 8 of them compared with the results of histologic examination The roentgen features appear to reflect the findings that hyaline membrane disease may have a lobar distribution and may be complicated by significant pulmonary inflammation Difficulties and limitations of the roentgenologic evaluation are considered

## ZUSAMMENFASSUNG

Atypische rontgenologische Lungenveranderungen bei 12 Neugeborenen mit schweren Atmungsstorungen werden besprochen und die Rontgenbefunde in acht von diesen Kindern verden mit den histologischen Erscheinungen verglichen Die Rontgenbefunde indikieren dass das hyaline Membran Syndrom mit einer lobaren Verteilung verbunden und durch Lungenentzundung kompliziert werden kann. D e Schwierigkeiten und die Begrenzungen der rontgenologischen Diagnose werden diskutiert

## RÉSUMÉ

Les auteurs décrivent les aspects radiologiques atypiques des poumons de 12 nouveaux nes atteints de syndrome de detresse respiratoire et les comparent dans 8 de ces cas avec les resultats de l examen histologique Les signes radiologiques paraissent correspondre au fait que la malad e de la membrane hyaline peut avoir une distribution lobaire et peut etre compliquee par une importante inflammation pulmonaire Ils examinent les difficultés et les limites du diagnostic radiologique

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grams (Fig 3) in atypical cases with lobes free of membranes were easily recognized

Neonatal pulmonary reticulogranularity either unevenly distributed or admixed with coarse atelectases should suggest the presence of combined disease and the possibility of a significant complicating disorder, inflammatory conditions should in particular be considered

Asymmetry and irregularity of distribution of reticulogranular pulmonary infiltration must be interpreted cautiously An apparent unilateral decrease in reticulogranularity may reflect the presence of a small pneumothorax on that side PETERSON & PENDLETON stated that a pneumothorax usually accentuates the reticulogranular pattern This is true when the volume of pleural air is relatively large and the lung has collapsed to the maximum of its markedly reduced compliance With a small pneumothorax, the air collected anteriorly in the supine infant will spuriously diminish the contrast of the lung structures Interstitial pulmonary emphysema preceding the development of a pneumothorax may cause sufficient bronchiolar and parenchymal compression to produce a reticulogranular pattern This however is usually of a coarse type and not to be confused with the delicate pattern observed in hyaline membrane disease

When the hyaline membrane process undergoes regression, an uneven pattern of resolution may occur Roentgen examination of the lungs may reveal an asymmetric and irregular distribution of reticulogranularity (RUDHE & BROBERGER 1967) which should not be misinterpreted as complicating or intercurrent disease, serial examination should serve to exclude this possibility

## Conclusions

Asymmetric, non-homogeneous reticulogranularity characterized the chest roentgenograms of eight neonates with histologically proven hyaline membrane disease These were roentgenographically considered atypical compared with thirty-three cases displaying characteristic, homogeneous reticulogranularity and in which the lung tissue was also available for study

Pulmonary lobes free of hyaline membranes were present in three of the eight atypical and in five of the twenty-three typical cases In the former group, these lobes were obviously free of disease roentgenographically In the latter group, however, diffuse atelectases throughout the lobes uninvolved by membrane formation produced roentgen features indistinguishable from adjacent lobes containing hyaline membranes

Irregularly distributed reticulogranularity in the remaining atypical cases probably reflected the presence of complicating inflammatory change, while interstitial and intra-alveolar hemorrhage present in four of these and in twenty one

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# RESIDUAL CONTRAST MEDIUM IN THE INTESTINES AND SIDE EFFECTS DURING CHOLECYSTOGRAPHY

## A comparison between some contrast media in current use and a new medium

by

SVEN ERIKSSON and GEORG-FREDRIK SALTZMAN

Oral cholecystography must today be regarded as one of our most reliable methods for [illegible]

[illegible] passage through the bile ducts is unobstructed. For two reasons, however, we have continued the search for better preparations. Some of the contrast substances have caused unpleasant side effects such as nausea, sometimes with vomiting, diarrhoea, and other reactions, and a few do not become completely reabsorbed, a considerable residue still being demonstrable in the intestines 12 hours after administration. The present paper describes an investigation to compare four of the contrast media most widely used for cholecystography, and a new preparation that promises to be a valuable and technically advantageous addition to our diagnostic aids. The main aspects studied were the

Submitted for publication 25 February 1969

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separated by a 12 hour interval HEALEY & GRAINGER reported nausea in 15 % of their cases BOGATZKI (1959), KEINER (1959), MULLER & SIELAFF (1959), GOERKE (1960), and STENHOUSE (1962) all found a low incidence of complications, a point of interest is that MULLER & SIELAF had given 6 g in a single dose CRECELIUS among 100 cases observed nausea in six and diarrhoea in one case after a dose of 3 g

*Present investigation* A comparative study on a uniform series of cases has been performed A series of 100 cholecystographies without evidence of pathologic changes, taken in succession without selection, was studied for each of four contrast media in current use, Telepaque, Bilijodon Natrium, Osbil, and Biloptin The administration of the substance and the roentgenographic technique were identical in every instance, the amount of contrast medium given was 3 g With few exceptions, all the patients were living in Stockholm at the time of the examination, and it is thus unlikely that differences in water affected the results

The investigation also included a series (100 cases) of cholecystographies without evidence of pathologic changes, in which the patients had received a new contrast medium, which at present goes under the working name of A 1579 This was also given in a dose of 3 g The radiopaque component of this prepara tion is the sodium salt of iopanoic acid, in other words the same as in Bilijodon-Natrium, the mode of preparation is however different

The resorption of an orally administered drug is often related to its solubility in water The dissolving rate of a preparation increases if its specific surface is increased, i e if its particle size is reduced Small particles may be obtained by mechanical micronizing or by precipitation under certain special conditions Both these methods have been tried with iopanoic acid, which in itself is not easily soluble Mechanical micronizing did not produce sufficiently small particles however and the particles obtained by precipitation proved to have low stability, they showed a tendency to rapid crystallization and to coalesce into larger aggre gates

Another way to encourage resorption is to prepare salts easily soluble in water When mixed with sour gastric juice the iopanoic acid is precipitated in the form of fine particles which, in theory, ought to be readily dispersable in gastric and intestinal juices Iopanoic acid, however, after precipitation of for instance its sodium salt, aggregates into large clumps which hinder its resorption These clumps are noticeably coarser than those that occur after administration of the acid as such Thus, neither of these two methods proved suitable

One way of preventing aggregation of the contrast medium in the gastric juice is to add a surface active constituent, which preferably should lack disturbing pharmacologic effects The surface active agents previously used, such as

presence of residual contrast medium in the intestines, and the occurrence of side effects

Among established contrast media, Telepaque (Winthrop), Biliodon-Natrium (Leo), Osbil (Byk-Gulden), and Biloptin (Schering), officinally described as iopanoic acid, the sodium salt of iopanoic acid, the sodium salt of iobenzamic acid, and the sodium salt of iopodoic acid, respectively, were selected for study

Several authors have reported a residue in the intestines with the first two preparations although the frequency figures differ widely For Telepaque, incidences ranging from 50 to 100 % of all examinations have been mentioned, and an even greater divergence is reported for Biliodon-Natrium, the figures varying from under 10 % to 90 % ANDRÉN & THEANDER (1960) have attempted to explain these large variations They have demonstrated that residual material is more often observed in the intestines when the whole abdomen is investigated (90 %) than when a conventional examination taking in the gall-bladder region alone is performed (60 %) They stated that the variations in some cases might be explained by varying degrees in the hardness of the drinking water, in other words that different drinking waters, when combined with the contrast medium, might to a varying extent form salts that dissolve slowly and are not readily absorbed A study of the literature suggests that Biliodon-Natrium leaves *a smaller residue than Telepaque, although no such difference* was observed by ANDRÉN & THEANDER

The frequency of residual material after the use of Biloptin is considered low It has been stated in general that no disturbing precipitation of contrast medium into the intestines occurs if the dose is kept at 3 g (CRECELIUS 1959, GOERKE 1960, WILBRAND 1961, HEALEY & GRAINGER 1965) Not even with 6 g, given in two doses of 3 g each, separated by an interval of 12 hours, did WHITESIDE obtain any residue MULLER & SIELAFF (1959) however noted a considerable residue in the colon in films taken 5 hours after the administration of 6 g in a single dose

Side reactions have been reported to be common with both Telepaque and Biliodon-Natrium According to PETERHOFF (1956) and others, a dose of 3 g causes nausea or diarrhoea in roughly a third of all cases HEALEY & GRAINGER mentioned a much higher frequency for Telepaque, however The incidence seems to be proportional to the size of the dose, and approximately the same for both preparations

The reports on side effects from Biloptin also vary Whereas WHITESIDE (1960) and MURRAY (1962) noted nausea, in some cases with vomiting, diarrhoea and headache, in over half of their cases, SALTZMAN (1960) observed no reactions at all among his first 45 cases WHITESIDE and MURRAY had however given their patients a double dose (6 g) divided into two doses of equal size,

A 1579 were asked to reply to the simple question "Did you experience any discomfort after swallowing the medicine?" No attempts were made to draw any information on subtle and consequently uncertain reactions

The incidence of side effects from these three preparations, with 100 cases tested in each group, was for Osbil and for Biloptin 6 % (five cases of nausea and one case of diarrhoea in each), and for A 1579 it was 11 % (ten cases of nausea and one case of diarrhoea)

None of these preparations produced any appreciable reactions. Compared with the incidence of side effects after Telepaque and Biliodon-Natrium (30 to 35 % formerly reported), that recorded for Biloptin, Osbil and A 1579 may be said to be low These three preparations thus seem to be in a class on their own among those at present available for oral examination of the biliary tract A 1579

number of cases of nausea, another study was carried out in a new series of 100 cholecystographies in which the patients were given dragées made in a machine Only three patients in this series complained of nausea although eight patients had diarrhoea The side effects thus remained unchanged in the total frequency but seemed to have altered in character

Residual contrast medium in the intestines was observed in five patients in whom the machine-made dragées were used

Telepaque, Biliodon-Natrium, Osbil and Biloptin are well-established contrast media with well known cholecystographic properties As no reports on A 1579 are as yet available there seems to be justification for giving a brief account of experience in clinical trials with this preparation

The contrast density of A 1579 is good, and fully equal to that obtained with other contrast media The authors have investigated 46 cases in which pathologic changes appeared to be present No contrast filling of the gallbladder was obtained in fourteen of the cases, half of which were operated upon Pathologic changes that could well have been the explanation of the absence of filling of the gallbladder were present in every instance The incidence of residual contrast medium in the intestine as well as of side effects was the same as in the normal cases.

## Conclusions

Considerable differences were observed between the contrast media investigated in this study From the aspects of the residue left in the intestines and the side

Tween 80 and peanut oil, have had an appreciably contractive effect on the gallbladder, however, and attempts to find a suitable agent were therefore directed towards those without a fatty acid component likely to have this effect

The surface active agent that best fulfilled these requirements was a non-ionic active polyol, this is a condensation product of propylene oxide and propylene glycol Polyol is a substance that is solid at room temperature and virtually tasteless and odourless It is soluble in water, stable to acids and alkalis and is not precipitated by metal ions, it is not metabolized in the body and has an acute oral toxicity expressed as $LD_{50}$ of 15 g/kg rat A preparation of equal parts of the sodium salt of iopanoic acid and the aforementioned surface active agent forms in artificial gastric juice (0 2 g NaCl and 1 5 g 5 M HCl in 100 ml water, pH 1 2 to 1 5) an extremely finely dispersed suspension with particles smaller than 1 $\mu$ There is no sign of crystal formation after an hour

## Results

*Residual contrast medium* The incidence of residual contrast medium demonstrated in the intestines after the administration of the different substances was as follows, the total number of cases in each group being 100

| | Per cent cases with residue |
|---|---|
| Telepaque | 74 |
| Biliodon-Natrium | 60 |
| Osbil | 22 |
| Biloptin | 5 |
| A 1579 | 3 |

This comparison reveals a fundamental difference between Telepaque and Biliodon-Natrium on the one hand and Biloptin and A 1579 on the other A small difference is apparent between Telepaque and Biliodon-Natrium, the incidence of residual contrast medium being slightly higher for Telepaque although on the other hand the residue was extremely fine-grained The residue from Biliodon-Natrium is coarser, a fact that sometimes causes difficulties in the interpretation of films of the gallbladder region Osbil occupies an intermediate position, the residue varies in appearance when this preparation is used but seldom causes diagnostic problems

*Side effects* These were recorded systematically only for Osbil, Biloptin and A 1579 As regards Telepaque and Biliodon-Natrium, their side reactions are so well known and the reports in the literature are so unanimous that further systematic study seemed unnecessary All patients who received Osbil, Biloptin or

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reactions, Biloptin, Osbil and A 1579 today appear to be the preparations of choice for cholecystography.

Biloptin and Osbil on the one hand and A 1579 on the other represent different lines of development in the work for improved contrast media. Two preparations, Biloptin and Osbil, which are definitely superior to those previously in use, have emerged in the trials of new chemical compounds. It must be *pointed out that the active substance in A 1579 is identical with that in Bilijodon-*Natrium, i.e. the sodium salt of iopanoic acid, but a new mode of preparation has led to improved results.


## SUMMARY

Four well-established contrast media for oral cholecystography, Telepaque, Bilijodon-Natrium, Osbil, and Biloptin, and a new preparation, A 1579, have been studied from the aspects of residues in the intestine and side reactions Biloptin, Osbil, and A 1579 appear to be better than the others A comparison between the side effects from hand-made and machine-made dragées of the A 1579 preparation suggested that there might be some connection between the coating and the nature of the side effects

## ZUSAMMENFASSUNG

Vier gewohnliche Kontrastmittel fur Cholezystographie, Telepaque, Bilijodon-Natrium, Osbil und Biloptin, sowie ein neues Kontrastmittel, A 1579, wurden in Hinsicht auf den Ruckstand im Darm und die Nebenreaktionen uberpruft Biloptin, Osbil und A 1579 scheinen in dieser Hinsicht besser als die anderen Kontrastmittel zu sein Ein Vergleich der Nebenwirkungen von bzw bei Hand und maschinell verfertigten A 1579-Dragées deutete darauf hin, dass ein Zusammenhang zwischen den Nebenwirkungen und der Art des Dragée Überzuges bestehe

## RÉSUMÉ

Les auteurs ont étudié les résidus intestinaux et les effects secondaires de quatre moyens de contraste bien connus pour la cholécystographie orale, Telepaque, Bilijodon-Natrium, Osbil, et *Biloptin, et un nouveau produit, A 1579 Le Biloptin, l'Osbil et le A 1579 paraissent* supérieurs aux autres produits La comparaison entre les effets secondaires de dragées de A 1579 faites à la main et des dragées faites à la machine fait penser qu'il peut y avoir un certain rapport entre l'enrobage des dragées et la nature des effets secondaires


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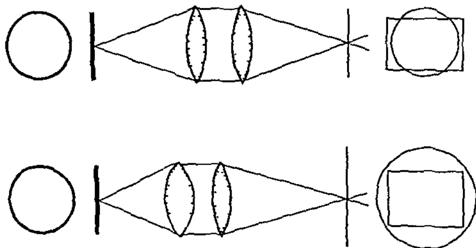


Fig 1 Path of rays in a conventional twin lens system (top) A magnification of the projected image obtained with the method described (below) Output screen to the left and film frame to the right

able conditions for small objects but were not sufficiently satisfactory for the special examinations now considered Tests with available standard equipments failed to produce satisfactory results and it was therefore necessary to modify the system

Direct magnification techniques utilizing roentgen tubes with subnormal focal size (0 3 mm) may be possible but if high speed record [illegible]
the highest

Another

connecting image intensifier and cinecamera. This was done. It is common experience that when a relatively small object is presented with a large screen intensifier the result is unsatisfactory, a fact that has led to the introduction of electronic magnification The richness of image details available, especially in the centre of the output screen, makes optical magnification possible It may be mentioned that for other purposes a magnification of the output phosphor image to 70 mm film size and over may be achieved with good result

In the conventional cineroentgenographic system the projection of the output screen is such that it utilizes the full surface of the film frame optimally This is a compromise between size of image and magnification For the 35 mm cinecameras this system is usually constructed according to the twin or tandem lens principle with 'equal area framing' (HOLM 1968), the image of the output screen being projected in the same size on the 35 mm cinefilm frame This

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# CINEROENTGEN EQUIPMENT FOR SMALL OBJECTS

by

OVE MATTSSON

The daily routine of a roentgen department often includes motility studies of small objects in the human body in which the study of detail is of importance Most image intensifiers have so large an input screen that the conditions for small objects are unfavourable The equipment now described would appear to constitute a solution of the problem and has given excellent results in clinical studies

Extremity surgery often demands motility studies of certain joints with cineroentgenography Studies of function are necessary, in particular for assessing the therapeutic aspects and the results of treatment of the joints of wrists and hands

Many intensifier tubes offer a possibility of direct electronic magnification to obtain an improved image of small objects This refinement is ordinarily available only in medium-sized or large tubes, the magnified image corresponding to a surface which is 5 inches (about 125 mm) in diameter compared with the normal 9 inches (about 230 mm) The gain obtained is however, due to electronic factors, accompanied by reduced intensification

Furthermore, an input surface reduced to 5 inches in place of the ordinary 9 inches offers no more than the early intensifiers with an input screen of 5 inches The latter, which are now practically out of production, provided more favour-

Submitted for publication 17 March 1969



Fig 3 Two radiographic frames from a motion study of the wrist

is limited by the aperture of the smaller of the lenses, the light output compared with that from a conventional twin lens system is reduced This means that the exposure must be increased, which is no disadvantage The effect of quantum mottle may be critical when employing magnification, however, if too small amounts of radiation are used The actual exposure increase is moderate but contributes to better detail identification

The apparatus has been used at speeds up to about 50 frames a second The focussing and adjustment of the object is easily made through the reflex viewfinder system of the camera connected to the lens system, and the cineroentgenographic recording can be followed continuously An increased camera speed should preferably be used, as the magnification makes motion blurr practically unavoidable Pulsing may prove advantageous

A study of the wrist in two frames is presented in Fig 3 The apparatus has also been used with success in studies of small changes in the oesophagus during deglutition and for the examination of the vocal cords

## SUMMARY

The optical system of an image intensifier-cinecamera combination may be changed to increase the central part of the output screen image so that more favourable conditions for the study of small objects are obtained The method is of special value in the study of function and the dynamic conditions of joints

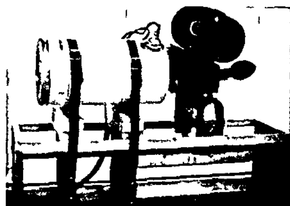


Fig 2 Apparatus for cineroentgenographic studies especially of small objects A 5 inch intensifier has been equipped with a modified lens system to give a more favourable recording scale on the cinefilm frame

method is usually well suited for conventional image intensifiers, the size of the projected image being suitable for the frame and constituting a compromise between its scale and detail size and the amount of detail lost outside the borders of the frame The conditions correspond to what is illustrated in Fig 1 (top), where the lens system is built up symmetrically As the objects considered fill up only the centre of the image field, a modification is introduced which allows the output phosphor image to be projected onto the film frame with the central part magnified, in other words with a 'blowing-up' of the central part of the image

The modification has been achieved in the following manner A conventional 35 mm Arriflex camera for professional movie use was combined with an ordinary 5-inch Philips intensifier, and a special modified lens system was introduced between the output phosphor image and the film frame The combination of two anastigmatic lenses, one of comparatively small and the other of greater focal length may produce the desired effect (Fig 1) The linear magnification compared with a symmetrical twin lens system can then be expressed for arbitrary values of focal length as $M = f_1/f_2$

In the equipment presently used (Fig 2), anastigmatic lenses with focal lengths of 35 and 50 mm, as well as 28 and 50 mm, were employed Enlargements of about 40 % and 80 %, respectively, may be obtained The method was developed after experiments with both 16 mm and 35 mm systems and with various lenses

It should be pointed out that there is often a certain vignetting effect in connection with most image intensifiers and the definition of the peripheral parts of the image, excluded in this technique, are often reduced in definition as well as underexposed By reduction of the primary radiation at the centre of the input screen all unnecessary radiation may also be screened off, which is of advantage for the image contrast

Because of the magnification and the fact that the diameter of the light beam

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK FINLAND NORWAY AND SWEDEN

Vol 10 Fasc 2 | DIAGNOSIS | 1970 March

# ANGIOGRAPHY IN INTRACRANIAL CAVERNOUS HEMANGIOMAS

by

HUGO BOGREN, CHRISTIAN SVALANDER and INGMAR WICKBOM

Only a few reports have appeared in the literature dealing with the radiologic findings in cases of intracranial cavernous hemangioma We have not been able to find any report of a proved case with angiographic changes typical or suggestive of the condition The angiographic findings in four proved and one possible case of intracranial cavernous hemangioma are now presented Four of the cases were intracerebral and one extracerebral

## Case reports

*Case 1* (Fig 1) A male who was 36 years old when first examined in 1953 He had then had frontoparietal headache for 5 years and occasional attacks of blurred vision No abnormality was found at angiography (only 3 films at about 2 second intervals had been obtained) or at encephalography apart from moderate widening of the anterior horns

In 1961 the patient was re admitted because of his first grand mal seizure Electroencephalography disclosed a focal abnormality in the right frontotemporal region, which had been present in 1958 but not in 1953 Encephalography revealed a subfrontal mass on the right side (Fig 1a) At carotid angiography (Fig 1b) of the same side, an unusally wide vein ran from the anterior part of the cingular gyrus above the corpus callosum around

From Roentgen[illegible]

## ZUSAMMENFASSUNG

Man kann das optische System einer Kombination von Bildverstarker und Cinekamera derartig modifizieren, dass man durch Vergrosserung des Zentrums des Schirmbildes eine bessere Beobachtung von kleinen Objekten erhalt. Die Methode ist von besonderem Wert bei Funktionsstudien der Gelenke.

## RÉSUMÉ

Il est possible de modifier le système optique d'un ensemble intensificateur d'image cine camera pour agrandir la partie centrale de l'image de l'ecran de sortie pour etudier dans des conditions plus favorables de petits objets. Cette méthode a un intérêt particulier dans l'etude de la fonction et des conditions dynamiques des articulations.

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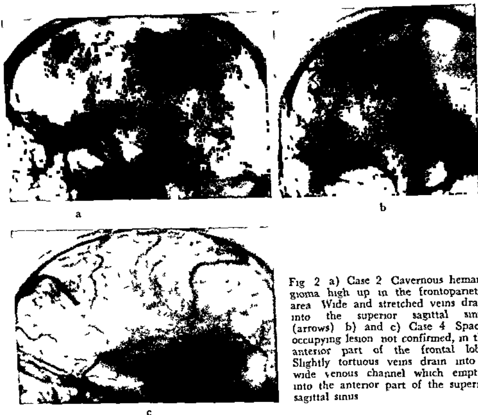



Fig 2 a) Case 2 Cavernous hemangioma high up in the frontoparietal area Wide and stretched veins drain into the superior sagittal sinus (arrows) b) and c) Case 4 Space occupying lesion not confirmed, in the anterior part of the frontal lobe Slightly tortuous veins drain into a wide venous channel which empties into the anterior part of the superior sagittal sinus

cerebral arteries appeared normal Microscopically the mass was found to be composed of thin walled blood spaces, varying in size and closely packed in the central part but partly separated by gliotic brain tissue towards the periphery There was no capsule Thrombosis of varying age was present in some of the blood spaces but most of them were patent Residues from earlier haemorrhages with phagocytes loaded with iron containing pigment were seen The tumour had no resemblance to hemangioendothelioma or glioma

*Case 2* (Fig 2a) Male, aged 35, with a history of rapidly progressing weakness of the left arm and leg ending in spastic hemiplegia He had also had vertigo and severe headache for some time Right side central abnormality was recorded at electroencephalography Right side carotid angiography revealed a space-occupying lesion high up in the fronto-parietal region displacing the vessels in an arched manner No tumour vessels were present but the veins draining that area filled early and remained filled a little longer than other veins

At operation, a hematoma was evacuated and at autopsy a few days later microscopy revealed structures of a cavernous hemangioma in the margin of the cavity In addition, there was another small cavernous hemangioma in the left occipital lobe (left side angiography had not been performed)

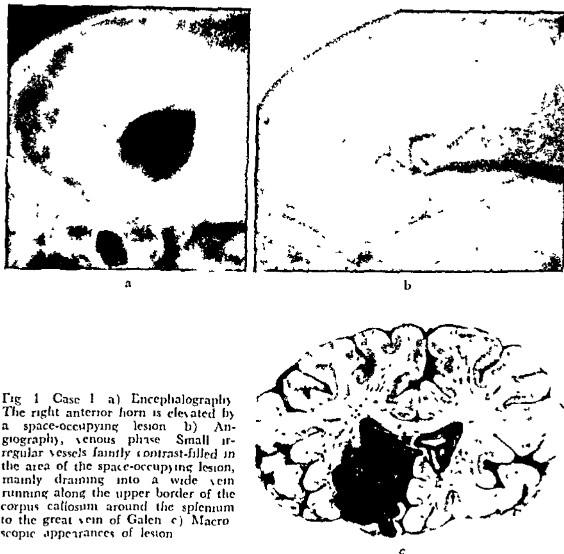



Fig 1 Case 1 a) Encephalography The right anterior horn is elevated by a space-occupying lesion b) Angiography, venous phase Small irregular vessels faintly contrast-filled in the area of the space-occupying lesion, mainly draining into a wide vein running along the upper border of the corpus callosum around the splenium to the great vein of Galen c) Macroscopic appearances of lesion

the splenium, to empty into the vein of Galen No abnormal vessels could be detected in the routine series of films (with 6 films at 1-second intervals) However, a repeat series with more films during the venous phase revealed irregular faintly filled vessels in the area of the subfrontal mass emptying into the wide vein The vein appeared at about the same time as other cerebral veins but remained filled for a longer time A less wide vein from the same area emptied into the sphenoparietal sinus There was no obvious displacement of vessels When reviewing the angiographies from 1953 the large vein could be seen but was only faintly contrast-filled and appeared less wide The patient refused operation

Encephalography and angiography were repeated in 1964 with the same findings as in 1961

At the end of 1966 the patient died in a status epilepticus, at autopsy a mass was found *medially in the right frontal* lobe The tumour was fairly well circumscribed, dark brown in colour, and 2 5 cm in diameter The vascularization in the vicinity was not increased The



Fig 4 Astrocytoma grade II in the anterior part of the frontal lobe A number of veins draining the tumour empty into the internal cerebral vein

sinus was displaced downwards and incompletely filled some wide veins were seen just anterior to this Left external carotid angiography revealed no abnormality

An extracerebral tumour not infiltrating the sinus was removed at operation The histologic diagnosis was that of cavernous hemangioma Since operation the patient has been free of symptoms

## Discussion

*Pathologic features* Cavernous angiomas of the brain and meninges are considered as extremely rare vascular malformations or hamartomas (Pool & Potts 1965) They are not true neoplasms but may appear malignant in some respects, e g they sometimes increase in size The relationship to capillary telangiectasis has been a matter of dispute Some authors regard the cavernous angioma as a stage of evolution from the telangiectasis (Russell 1931) and term both telangiectases (Wyburn & Mason 1943) This is not accepted by others The lack of conformity in terminology no doubt makes it difficult to compare the different data published, even more so since sometimes no clear definition nor any description of the histologic appearances of a lesion are included

Cavernous angiomas have certain morphologic characteristics distinguishing them from other types of angiomatous malformations in the brain Microscopically they should be well delimited, but usually not encapsulated, and composed of closely packed vascular channels, often wide but with considerable variation in size The blood spaces are thin-walled, with single endothelium, and should at



Fig 3 Case 5 Veins displaced in the region of the defect, just anterior to which lies a wide, irregular, densely filled vein

*Case 3* Female, aged 18, was admitted because of grand mal seizure, preceded by severe frontal headache Electroencephalography recorded a right-side frontotemporal focus The vessels at angiography were seen to be displaced around an area of about 3 cm diameter in the frontal pole No abnormal vessels were seen Veins in the area filled and emptied in about the same time as other veins The lesion was removed and was at microscopy found to be a cavernous hemangioma

*Case 4* (Fig 2, b and c) Male, aged 45, was admitted because of right-side grand mal seizures and frontal headache He had had one seizure 21 years prior to admission but had otherwise been healthy Electroencephalography showed no definite abnormality

At carotid angiography on the left side a wide vein was seen in the right frontal lobe, right side angiography was then performed Small tortuous vessels were seen in the anterior part of the frontal lobe in the late arterial and early venous phase within a rounded area of about 2 cm diameter The vessels drained into a wide vein leading to the superior sagittal sinus This vein was filled about one second before the other veins on the convexity and remained so for a longer time

Angiography was repeated 6 weeks later with the same findings Bilateral angiography repeated again 9 months later produced the same appearances

Encephalography has been performed on three occasions and each time the right ventricle failed to fill with air The patient's condition is now, two and a half years after the first examination, about the same Operation has so far not been performed, partly because the angiographic changes have suggested a hemangioma rather than a true neoplasm

*Case 5* (Fig 3) Male, aged 56, who during the previous 6 years had had attacks of headache lasting from a few hours to a few days During the same time he had noticed a tender spot in the parietal region close to the midline, and in the last year a tender fluctuating tumour had developed in the same area A polycyclic bony defect, with a diameter of 3 to 4 cm, corresponding to the lump, was observed at skull examination At left internal carotid angiography the small arteries in this area were displaced from the vault and the sagittal

graphy, but the diagnosis was not confirmed The same is true about Case 2 of the two cases of intra-orbital cavernous hemangiomas, reported by DILENGE et coll (1965) Judging from the illustration this lesion appears more compatible with an arteriovenous malformation than a cavernoma In their Case 1, which was confirmed although the histologic findings were not mentioned, they described the mass as becoming opaque although this is hardly evident from their illustrations

The non filling of cavernous hemangiomas has been ascribed to the fact that few vessels in general enter the formation (SCHNEIDER & LISS 1958) ROBINSON et coll (1966) stated that the cavernous hemangioma, in contrast to the arteriovenous malformation, usually lacks large afferent vascular channels and its internal circulation is therefore frequently sluggish

No feeding arteries could be demonstrated at angiography in the present cases The irregular and faintly filled veins seen in Cases 1 and 4 may represent some of the cavernous vascular channels in the lesion but are probably only draining veins The small veins in Case 1 were not obvious without a rapid serial technique and a larger amount of contrast medium The most striking angiographic feature consisted of large draining veins in all cases except maybe Case 3 In two cases (Cases 2 and 4) they filled early and in two cases (Cases 1 and 4) remained filled for a longer time than other veins During the arterial phase the cavernomas appeared only as avascular masses

In disagreement with these findings RUSSELL & RUBINSTEIN (1963) failed to identify enlarged draining veins from cavernous hemangiomas at *autopsy, but* they may of course be overlooked if collapsed BLACKWOOD (1941) *on the other* hand found enlarged draining veins from capillary telangiectases at *autopsy* Angiographic appearances of the kind demonstrated in the *present cases are,* however, not pathognomonic, as evident from the case illustrated *in* Fig 5 *In* this case, the wide veins draining the tumour area and emptying into the internal cerebral vein were similar to those demonstrated in the *present cases* of cavernous hemangioma, they filled a little later than *the other* cerebral veins but remained filled *for a longer time* The diagnosis suggested by microscopy was *grade II* astrocytoma

Angiographic findings similar to those *in cavernous* hemangiomas have been described in cases of Sturge *Weber's disease* (*GREEN & ARANA 1948,* WAPPENSCHMIDT 1967), but the clinical entity in this condition is usually typical and characteristic calcifications are usually *present*

CURTIS (1949) in an unverified case described a *slow* accumulation of contrast medium in the angioma followed by an equally *slow venous* drainage

The reason why the angioma itself does not *fill out* may be due to a small calibre of the feeding arteries and a slow circulation, or extensive thrombosis, or




Fig 5 Angiography of a cavernous hemangioma in the thigh Arterial (a) and venous phase (b) after arterial injection and after direct injection into the angioma (c) Only part of the lesion is demonstrated after arterial injection

least in the central part not be separated by cellular substance Signs of thrombosis, haemorrhages of different age, as well as organisation, sometimes with calcification may occur (RUSSELL & RUBINSTEIN 1963) Four of the present cases had histologic characteristics in conformity with this description Case 2 *is an* example of a small cavernous angioma, associated with intracerebral haematoma It is evident that the hemangioma causing a haematoma may easily be overlooked unless careful microscopic examination is performed

*Angiographic appearances* We have not been able to find any report in the literature of a proved case of cavernous hemangioma in the brain demonstrated at angiography Previously reported cases have been described at angiography or encephalography only as expanding lesions (FURTADO et coll 1951 one case, SCHNEIDER & LISS 1958 three cases with angiography performed in one case, JAIN 1966 one case of intraventricular cavernous hemangioma with calcifications, ISHIJMA et coll 1966 two cases, one of which was examined with carotid angiography) In KAMRIN & BUCHSBAUM's (1965) two confirmed cases and in the case published by ROBINSON et coll (1966) nothing abnormal was recorded at angiography CURTIS (1949) on the other hand reported a case of what he thought to be an intracerebral cavernous hemangioma, contrast-filled at angio-

graphy, but the diagnosis was not confirmed The same is true about Case 2 of the two cases of intra-orbital cavernous hemangiomas, reported by DILENGE et coll (1965) Judging from the illustration this lesion appears more compatible with an arteriovenous malformation than a cavernoma In their Case 1, which was confirmed although the histologic findings were not mentioned, they described the mass as becoming opaque although this is hardly evident from their illustrations

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CURTIS (1949) in an unverified case described a slow accumulation of contrast medium in the angioma followed by an equally slow venous drainage

The reason why the angioma itself does not fill out may be due to a small calibre of the feeding arteries and a slow circulation, or extensive thrombosis, or

a combination of both BARTLEY & WICKBOM (1959) in their examination of soft tissue cavernous or venous hemangiomas sometimes observed wide vascular channels or lakes that filled in the late phase and remained outlined for a considerable time. They could however not always be demonstrated after intra-arterial injection but only after introduction of the medium directly into the lesion.

In a case of cavernous hemangioma of the thigh examined in our department only part of the lesion was filled after arterial injection, injection directly into the hemangioma produced however filling of wide vascular channels. The non-filling in this case may accordingly not be attributed to thrombosis within the angioma. Nor was extensive thrombosis seen in any of the cases of intracranial cavernomas. The findings thus seem to support the view of SCHNEIDER & LISS (1958) and ROBINSON et coll. (1966) that cavernous hemangiomas lack large afferent vessels.

The series is small but there would appear to be justification in diagnosing a cavernous hemangioma angiographically if wide veins seem to drain a space-occupying lesion, apparently poor vascularization of the latter and prolonged contrast-filling of the veins support the diagnosis.

## SUMMARY

Four proved and one unconfirmed case of intracranial cavernous hemangioma examined with carotid angiography are reported. Wide draining veins, in some cases contrast filled for a fairly long time, were demonstrated in spite of the fact that no abnormal vessels could be defined in the lesion itself. The significance of the angiographic findings is discussed.

## ZUSAMMENFASSUNG

Es wird über vier Fälle von bestätigtem und einem Fall von unbestätigtem cavernösen Haemangiom des Schädels berichtet. Alle Fälle waren mittels Carotisangiographie untersucht. In allen Fällen zeigten sich weite und ziemlich andauernd gefüllte Abflussvenen obwohl keine abnorme Gefässe im Tumor gesehen wurden. Die Bedeutung der angiographischen Befunde wird besprochen.

## RÉSUMÉ

Présentation de quatre cas prouvés et d'un cas non confirmé d'hémangiome caverneux intracrânien examinés par angiographie carotidienne. Il y avait de larges veines de drainage qui dans certains cas restaient opacifiées pendant un assez long temps bien que l'examen n'ait pas montré de vaisseaux anormaux dans la lésion elle-même. Les auteurs examinent l'intérêt des signes angiographiques.

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# FIBROMUSCULAR HYPERPLASIA OF THE CAROTID ARTERIES

by

POUL E ANDERSEN

Since the rediscovery of fibromuscular hyperplasia of the renal arteries by WYLIE & WELLINGTON 1960, more intensified angiographic efforts to demonstrate corrigible causes of arterial hypertension have brought to light an increasing number of cases of extrarenal arterial dysplasia, a term proposed by HUNT et coll (1962), and HILL et coll (1965) During the period 1964—1966, PALUBINSKAS et coll and WYLIE et coll (1966) have reported a number of cases with carotid systems having angiographic appearances typical of fibromuscular hyperplasia of the renal arteries The first histologically verified case of fibromuscular hyperplasia of the carotid arteries, however, was published by CONNETT & LANSCHE (1965)

This was followed in 1967 by a report of a case by EHRENFELD et coll, a case by RAINER et coll (1968) and three cases by MORRIS et coll (1968) These were mainly of young middle-aged women with signs of intermittent, transient cerebral ischemia and were often cured by resection of the stenosed area The cases reported by other authors (e g WYLIE et coll 1966) also had a considerable female preponderance while the occurrence in children seems to be extremely rare (ANDERSEN, to be published)

The author during the past two years has had the opportunity of observing four cases of fibromuscular hyperplasia of the carotid arteries, one of which was in a

Submitted for publication 23 May 1969



Fig 1 Case 1 Fibromuscular hyperplasia of the internal carotid artery below and above the carotid canal Saccular aneurysm with typical spasm following hemorrhage



Fig 2 Case 2 Typical 'string of beads' configuration of the external carotid artery, with slight post stenotic dilatation at the level of first and second cervical vertebrae

male child and two in elderly women dying from rupture of cerebral saccular aneurysms, thus corroborating the hypothesis of WYLIE et coll The cases were histologically verified and presented the typical microscopic appearances described in the literature (HUNT et coll 1962, HARRISON et coll 1967, MACDONALD & McMILLAN 1963, SUTTON et coll 1963, WYLIE et coll 1966) As both the female patients died from subarachnoid hemorrhage, the present paper may serve the purpose of calling attention to the possibility of intracranial aneurysms occurring in a high percentage of cases of fibromuscular hyperplasia An at present asymptomatic case of fibromuscular hyperplasia in the external carotid artery is also reported

## Case reports

*Case 1* A 54 year old woman was admitted after a week's illness to a small general hospital on account of several episodes of unconsciousness and convulsions preceded by intense headache for about 15 minutes She was said to have had a similar attack 4 years previously and on admittance was confused drowsy and slightly hypertensive There were no neurologic signs and a diagnosis of climacteric psychosis was made The drowsiness increased however central facial paresis and signs of a subarachnoid hemorrhage developed and the patient was transferred to us

Carotid angiography by direct puncture disclosed a saccular aneurysm of the left anterior



a b

Fig. 3. Case 3. Fusiform aneurysm of right internal carotid artery, dilatation and configuration typical of fibromuscular hyperplasia. b) Lateral angiogram. Saccular aneurysm of anterior cerebral artery.

cerebral artery with typical spasm of the adjacent segments of the anterior and middle cerebral arteries (Fig. 1). The external extracranial part of the internal carotid artery presented the string of beads appearance characteristic of fibromuscular hyperplasia. Six hours later the condition of the patient deteriorated rapidly with brain stem convulsions and fall of blood pressure and she died before anything could be done.

At autopsy a saccular aneurysm and subarachnoid hemorrhage were observed in the inferior region of the left frontal lobe in accord with the arteriographic findings. The extracranial part of the left internal carotid artery and the left renal artery presented evidence of slight corrugations of the intima. Atheromatosis of the aorta was the only other macroscopic abnormality. Microscopy with hematoxylin eosin and elastin staining preparations of the distal part of the left internal carotid artery and the left renal artery revealed subintimal and medial fibrotic hyperplasia and fragmentation of the internal lamina elastica consistent with the criteria established by HUNT et coll. and WYLIE et coll.

*Case 2.* A 69 year old man was admitted because of a history of cerebral circulatory insufficiency. He displayed slight transient expressive aphasia on examination but a neurosomatic investigation revealed no abnormality and no arterial hypertension. Ophthalmoscopy and gamma encephalography were normal. EEG indicated periodic preponderance of low frequent activities in the left temporal region.

Carotid angiography was performed by low puncture of the left common carotid artery. No intracranial abnormality was present in the left anterior and middle cerebral arteries and their ramifications. The extracranial part of the internal carotid artery including the carotid bifurcation was not abnormal. The external carotid artery however from the origin of the main occipital artery and 3 cm distally was the site of a typical string of beads contour distinctly different from the standing waves which as reported by WICKBOM & BARTLEY (1957) often occur in the carotid arteries. The patient on account of the slight

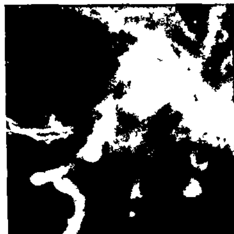



Fig 4 Case 4 *Left* Lateral angiogram Upper part of vertebral artery appears extensively corrugated *Right* Extensive lesion of the internal and external carotid arteries

and transient symptoms declined further examinations, thus, no histologic nor renal angiographic verification was obtained He was discharged free of symtoms and has remained so for the past two years

*Case 3* A 48 year old woman was admitted because of vomiting increasing confusion and somnolence after sudden headache She was obese and was known to have had arterial hypertension for at least 10 years, with frequent spells of headache for a period of about 2 years The cerebrospinal fluid was blood stained EEG presented marked changes

At carotid angiography a saccular aneurysm measuring about 10 mm × 5 mm was seen on the anterior communicating artery, with a hematoma in the right frontal lobe The patient s condition deteriorated rapidly into deep coma with right hemiparesis and marked arterial hypertension and she died before surgical intervention could be made The angiographic findings were confirmed at autopsy Sections disclosed typical plaques of sub intimal fibrosis and a varying calibre of the internal carotid artery, some of the plaques contained cholesterol crystals

*Case 4* Boy aged 8 years, represents a case that will be reported upon in detail in a subsequent paper (Andersen) At the age of 2 years he was found to be suffering from endocardial fibro-elastosis The prognosis was considered poor and no treatment was given Attacks interpreted as psychomotor epilepsy started at the same age Three years later a neurosomatic examination was normal and EEG had a spike focus over the left fronto temporal area and bilateral synchronous spike paroxysms The cardiac status was unchanged and the patient was placed on anti epileptic medication He was well at several controls, apart fr m having difficulty in running

The admission at the age of 8 years was caused by an influenza like state that had started 12 days earlier with fever, disorientation, and meningeal reactions Possible hemorrhage from a cerebral vascular malformation was suspected Bilateral systolic bruits were present over the carotid arteries but not over the femoral arteries EEG was grossly abnormal, with spike paroxysms over both temporal regions

Bilateral carotid and vertebral angiography by direct puncture disclosed extensive lesions of the fibromuscular hyperplasia type in all areas Encephalography indicated moderate cortical atrophy in the insular regions Nephro angiography revealed typical fibromuscular hyperplasia of both renal arteries A similar condition was noted in the hepatic, inferior mesenteric and some of the lumbar arteries Biopsy of the superficial temporal artery disclosed typical fibromuscular hyperplasia

The patient is now on anti epileptic medication and without cerebral symptoms His cardiac condition is controlled by digitalis and he is free from hypertension

## Discussion

The increasing number of cases of external fibromuscular hyperplasia reported during the past few years as well as the present cases indicate that the condition may affect any artery It manifests itself according to the physiologic effects on the arterial territory by stenosing or disruptive changes in the vessel As the stenotic process usually dominates, the ischemic symptoms are liable to prevail The disruptive effect on the arterial wall of the splitting of the internal elastic membrane may however well be the explanation of the absence of hypertension in at least one third of all cases of renal fibromuscular hyperplasia (ANDERSEN 1966) Case 1, which resembles the cases reported by WYLIE et coll (1966), had insignificant hypertension prior to the actual disease This is in accord with the fact that the kidneys were macroscopically normal and the renal arteries without stenotic lesions While the walls of the renal arteries were sites of fibromuscular hyperplasia the renal parenchyma was microscopically normal

No hypertension was present in the remaining three cases Cases 2 and 3 were not subjected to nephro angiography on account of the total absence of renal and hypertensive signs The arteriographic appearances were however typical and constant and bore no resemblance to the 'stationary waves' reported, e g by BELBER & HOFFMAN (1968), RAINER et coll (1968), STEINBERG (1966) or WICKBOM & BARTLEY (1957) The presence of an intracranial aneurysm in Case 3 also strongly corroborated the radiologic diagnosis

Contrary to the cases reported by other authors, e g MORRIS et coll (1968), the present Cases 1, 3 and 4 had typical angiographic fibromuscular hyperplasia changes in the intracranial part of the internal carotid arteries. Case 4 is especially remarkable on account of the extensive arterial lesions and the age of the patient This is the first child reported with histologically verified carotid and vertebral lesions The combination of endocardial fibroelastosis and fibromuscular hyper-

plasia is also interesting and suggests challenging hypotheses The fact that the simultaneous occurrence of fibromuscular hyperplasia and endocardial fibroelastosis had not previously been reported may perhaps be explained by the limited autopsies, interest being centered exclusively on the cardiac disease, the clinical signs of which in this age group (0 to 4 years) are impressive and tend to overshadow slight renal hypertension Normal macroscopic appearances of the renal and other abdominal arteries in spite of incipient microscopic fibromuscular hyperplasia changes (as in Case 1) also adds to the possibility of the condition being overlooked

No intracranial aneurysm could be demonstrated in Case 4 with vertebral artery involvement, as MORRIS et coll did in their case of possible vertebral fibromuscular hyperplasia It must however be admitted that the changes in all the intracranial vessels were so marked that one or more of the bulges may well have represented a small aneurysm The future course of this case will be interesting

The preponderance of female cases of fibromuscular hyperplasia (85 per cent), as demonstrated e g by PALUBINSKAS & NEWTON (1965), and the combination of the condition with intracranial aneurysm seem real and should be an indication for renal nephro angiography in all cases of subarachnoid hemorrhage, even if most occur in one isolated region, the American West coast A thorough angiographic analysis of each case of this syndrome must add valuable information regarding ethiologic factors


## SUMMARY

Four cases of fibromuscular hyperplasia of the carotid and vertebral arteries are reported The significance of the increasing manifestation of the condition in other regions is discussed Two of the cases are of females with an intracranial saccular aneurysm combined with fibromuscular hyperplasia Hypertension is not a prominent feature of the condition

## ZUSAMMENFASSUNG

Es wird uber vier Falle mit fibromuskularer Hyperplasie der Carotis und Vertebral arterien berichtet Die Bedeutung der Ausbreitung dieser Erkrankung auf andere Korper regionen wird erortert Zwei Patientinnen hatten ausser der fibromuskularen Hyperplasie cerebrales sakkulares Aneurysma Hochdruck in diesen Fallen ist nicht hervorragend

## RÉSUMÉ

L auteur presente quatre cas d hyperplasie fibromusculaire des arteres carotides et vertébrales Il examine l importance de l aggravation des manifestations de cette affection *dans* d autres *regions* Deux de ces cas sont des femmes qui presentent un anévrysme sacculaire intracranien associé à une hyperplasie fibromusculaire L hypertension n est pas un caractère important de cette affection

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# EMBOLIC COMPLICATIONS IN CEREBRAL ANGIOGRAPHY WITH THE CATHETER TECHNIQUE

by

S CRONQVIST, H O EFSING and E PALACIOS

Complications in angiography depend mainly upon the technique (SCHEINBERG & ZUNKER 1963, ALLEN et coll 1965, AMUNDSEN et coll 1963) The present contrast media probably play only a minor role (MARGOLIS et coll 1958, TONNIS & SCHIEFER 1959, LANG 1963)

The techniques in cerebral angiography consist of direct puncture and catheterization Direct punctures of the carotid and the vertebral arteries have been most commonly used to date These methods possess however obvious drawbacks The difficulty in keeping a needle in position in vertebral angiography is well known (CRONQVIST 1961) and the same applies to carotid angiography Sub intimal or even extravasal injections of contrast medium are common (ALLEN et coll 1965) The development of an arteriovenous fistula following needle puncture has been reported (OLSON et coll 1963, LESTER 1966) and intracranial embolization has been described (RIMPAU & SEILS 1957, DECKER 1960, EIKEN & GORMSEN 1962, ZATZ & IANNONE 1966) This may be due to dislodging of small clots formed within the needle or of tissue particles trapped in the lumen of the

Submitted for publication 21 March 1969

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Fig 1 Case 2 Small f lling defect at the d v is on of one of the Sylvian vessels (a) The patient developed trans tory neurolog c s gns One week later entirely normal angiography (b)

before the examination proceeds The wire guide is thoroughly cleaned between each procedure

## Case reports

*Case 1* Woman aged 5? with signs of subarachnoid haemorrhage starting 3 weeks before admission Angiography with catheterization of the right and left carotid arteries was normal The catheter was then once again placed in the right carotid artery for further films The speech of the patient was impaired in connection with the injection of contrast medium Now a 2 mm long filling defect not previously present was observed in one of the Sylvian vessels the passage of the contrast medium through the partially occluded vessel was exceptionally slow The clinical signs were transitory and complete recovery o curred within minutes

*Case 2* Man aged 46 with headache (Fig 1) Ophthalmoneurologic examination on admission revealed papillary stasis and encephalography demonstrated a suprasellar tumour B lateral carotid angiography with catheterization from the femoral artery was performed The right angiogram was normal The left carotid artery was then catheterized and contrast material was injected Five minutes later the patient complained that he could not move the fingers of the right hand some minutes later his speech was impaired The symptoms gradually disappeared Angiography then disclosed an embolus at the bifurcation of one of the Sylvian arteries

*Case 3* Boy aged 10 years was brought to the hospital with left sided seizures and conjugated deviation of the eyes to the right s de EEG showed a focus on the right side Right

needle when penetrating the soft tissue Mobilized thrombotic material from a punctured atheromatous plaque is also thought to cause embolization, and emboli *formed by foreign substances,* such as cotton fibres, have been described (ADAMS et coll 1965)

The catheter technique was first introduced by ICHIKAWA (1938) and FARIÑAS (1941) and was successfully applied in vertebral angiography by RADNER in 1947 The development of the SELDINGER instrumentarium in 1953 further encouraged the use of this method Its value in vertebral angiography is by now well established (CRONQVIST 1961) but it has also been increasingly applied in angiography of the carotid artery either by introduction of the catheter from the brachial, axillar or femoral arteries, or by direct catheterization of the common carotid artery (AMUNDSEN et coll 1963) One point in favour of this technique is that it is probably without most of the drawbacks encountered with direct needle puncture Furthermore, catheterization from the femoral artery causes only minor discomfort to the patient It permits selective catheterization of the external and *the internal carotid arteries after demonstration of the common carotid artery* and enables the examination of more than one vessel in the same sitting

Complications due to the technique with the catheter are however known to occur Single reports on cerebral embolization in addition to local complications such as haematoma, local spasm, have been published Seven such cases are reported in this paper to stress the existence of the risk The angiographic changes and the clinical symptomatology compatible with the occurrence of acute embolization arising from an angiographic examination, together with preventive measures, will be discussed

*Technique* Vertebral and, in selected cases, carotid angiography are performed with catheterization via the femoral artery The proportion at our department of direct to indirect approaches in the carotid examinations is about 50 50 A red Ödman-Ledin catheter is generally used, either a thin walled catheter with an outer diameter of 1 8 mm and an inner diameter of 1 2 mm, or a thick walled with an outer diameter of 2 2 mm and inner diameter of 1 2 mm No side holes are introduced The catheter is shaped in a more or less marked S form according to the age of the patient and the vessel to be examined Thus the S has a sharper curve for the left than for the right carotid artery and for examining older patients During the examination the catheter is intermittently flushed with saline during the period it takes to manipulate it in the correct position as well as when it is properly sited If more than one vessel is to be examined the catheter tip is brought down into the lower part of the abdominal aorta in between catheterization of the individual vessels The guide wire is then passed through the catheter to control free passage of blood through the lumen and the catheter is flushed



Fig 3 ... cereb... a ma... of or...

of the middle cerebral artery not previously present was now seen Peripheral to the defect the arteries were wider than normal and local slowing down of the circulation was noted No neurologic signs developed in connection with the angiographic examination which was technically easy and rapidly performed

*Case 6* (Fig 4) Man aged 44 who had developed left-side paresis About one month later angiography of the right internal carotid artery was performed with a catheter via the right femoral artery, and a small avascular expansive lesion in the parietal region was demonstrated There were no signs of vascular occlusion An additional angiographic examination was performed at the same session with the catheter in the common carotid artery and partial occlusion of a peripheral artery in the parieto-occipital region was demonstrated in the angiogram The passage of contrast medium through the vessels was exceptionally slow in comparison with that in the other arteries The vessel also appeared markedly dilated compared with its width at the first injection No neurologic signs developed

*Case 7* (Fig 5) Woman aged 45 operated on 4 years previously for an angioblastic parasagittal meningeoma in the occipital region, complained of pain in the left ear In spite of no neurologic signs further angiographies were performed The examinations were carried out with a catheter via the femoral artery and commenced with left carotid angiography Injections were made first into the external and then into the internal carotid artery with filling of a normal left posterior cerebral artery At subsequent left vertebral angiography a 7 mm long filling defect was present in the previously normal posterior cerebral artery The patient developed no neurologic signs

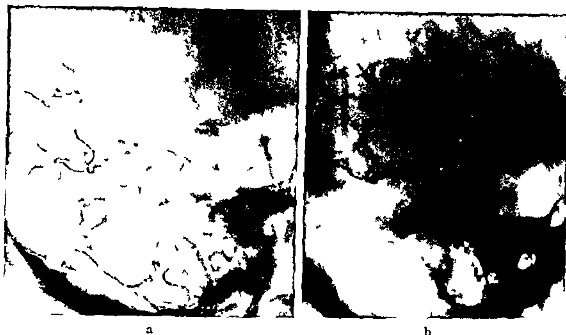


Fig 2 Case 4 Normal vertebral angiography (a) Carotid angiography (b) performed immediately after showed *a collateral circulation to the peripheral branches of the posterior* cerebral artery This case represents an example of indirect signs of acute embolization

sided carotid angiography via a catheter from the right femoral artery was performed under *general anaesthesia and two film series were taken in lateral projection In the first series* multiple occlusions were noted with a contrast blush and early filling of local veins in the *region of the occlusion The second series obtained five minutes later presented completely* normal conditions Neurologic examination after the patient had recovered from the anaes*thetic revealed no new clinical signs*

*Case 4* (Fig 2) *Woman aged 42 with acute headache was admitted and the diagnosis* of subarachnoid haemorrhage was made Bilateral carotid angiography and vertebral angiography *were performed Right carotid angiography was normal This was followed by a* left side vertebral catheterization via the femoral artery with entirely normal findings *These examinations were completed with left carotid angiography and retrograde filling* of arteries corresponding to peripheral branches of the posterior cerebral artery was now present *This artery had been normally filled in the preceding vertebral examination* There were thus indirect signs that an occlusion had suddenly occurred in the artery There were no *neurologic signs*

*Case 5* (Fig 3) Man aged 50 with papillary stasis had been examined at another hospital with angiography of one vertebral artery and of both carotid arteries No gross changes were reported but the sagittal sinus was not properly seen Thrombosis of the latter was considered probable hence a repeat left carotid angiography was performed with the catheter introduced via the right femoral artery A local filling def




Fig 5 Case 7 Vertebral angiography (a) disclosed a filling defect in the posterior cerebral artery This artery a few minutes later was seen to fill normally at carotid angiography (b)

between 3 and 6 per cent with about 80 per cent of lesions transient Fatalities occurred in 0 7 per cent of cases The number of cases of embolization was unknown

Reports on complications with the catheter technique are predominantly based upon experiences from abdominal and thoracic angiography (McGRAW 1963 KOTTKE et coll 1964 LANG 1966 SEIDENBERG & HURWITT 1966) These mainly deal with changes at the puncture site and within the vessels caused by the wire guide or by the catheter itself i e a local haematoma and arterial spasm (WICKBOM & BARTLEY 1957)

A large number of procedures 11 402 in all were collected and recorded by LANG (1963) who reported a mortality rate of 0 06 per cent and a serious complication rate of 0 7 per cent Thromboembolic complications were noted in nine of the cases corresponding to 0 07 per cent

Data on complications in cerebral angiography performed with the catheter technique are scarce Some information is available in earlier work on vertebral angiography by RADNER (1947) and by HAUGE (1954) but to our knowledge little has been written regarding the technique applied today FLEVIN (1960) reported his experiences with the catheter method in carotid ang[illegible]
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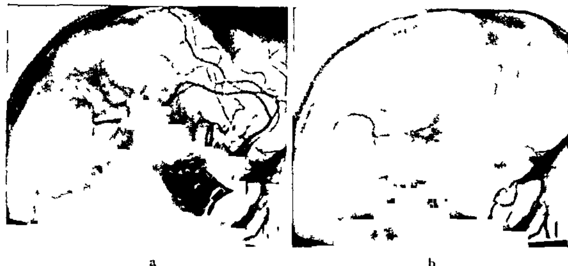



Fig 4 Case 6 Normal internal carotid angiography in (a) Subsequent common carotid angiography (b) showed occlusion of a peripheral branch in the posterior parietal region No dilatation of occluded artery

## Comments

All but one of the seven patients had more than one vessel examined at the same sitting The duration of the procedures varied up to 80 minutes (Case 9 left internal and external carotid angiography and vertebral angiography) The contrast medium was Urografin 60 % In four cases, no neurologic signs developed in relation to the examinations Transient signs occurred in two cases, in one lasting only a few minutes and in the other about half an hour

The embolus was in one case demonstrated by an arterial occlusion It was directly seen in angiography as an intra-arterial filling defect in five cases, in one of which multiple defects indicated multiple emboli In the latter case, local accumulation of contrast medium was seen during the capillary phase and early filling veins were observed in the region of the embolized vessel Indirect signs of embolization, evident from the development of collateral circulation, were recorded in one case (Case 5) In addition to these signs there was almost always local slowing down of the passage of contrast medium in the partly occluded vessel which in some instances appeared markedly dilated

## Discussion

The incidence of complications in cerebral angiography performed with direct puncture is well documented SCHEINBERG & ZUNKER (1963) from data available in the literature determined that the frequency of cerebral complications varied

marked circulatory disturbances evident in the angiograms The signs may persist, but judging from the present series they appear to be mainly transitory in character In some of the cases they actually passed off so fast that only the constant observation of the patient during angiography revealed their occurrence Slow regression of symptoms was noted in only one case, although complete return to normal was delayed until a week after the incident

The source of the embolus may be arteriosclerotic plaques from which atheromatous material is dislodged by the catheter On the other hand, the source may be the catheter itself Thus, clots have been reported to form within the side holes close to the tip of the catheter (ODIN 1953), and because of this the use of such catheters in selective angiography should be avoided (BOIJSEN & FEINSTEIN 1961)

JACOBSSON (1967) recently proved that a catheter introduced into vessels is coated by a layer of platelets and that these may form thrombotic masses on the surface of the catheter, and probably also within the lumen of the catheter unless flushed away The thrombotic material may easily get detached during the manipulation of the catheter and constitute the main source of emboli noticed during arteriography There is evidence that the adhesiveness of platelets increases when the catheter is a long one and there are reasons to believe that the more irregular the wall of the catheter the greater is the tendency for clot formation

The time during which the catheter remains within the vessel must also be of importance Consequently, only catheters with the smoothest surface should be used, and the examination time must be short From a practical standpoint this entails that when performing catheterization for angiography of more than one cerebral vessel the catheter should be changed between each examination A constant infusion of saline instead of intermittent injections may be of value in preventing the formation of intraluminal clots An additional precaution suggested and used by JACOBSSON in the infusion of macrodex prior to angiograph

[illegible] (GRONBERG et coll 1966)

The catheter method in comparison with direct needle puncture possesses many advantages in cerebral angiographic work The risk of embolization remains, however Since there are often no or only vague clinical indications that a vascular accident has occurred, there is a risk that an arterial embolization may be easily overlooked The risk of not making the diagnosis, and thus also of getting a false impression of the safety of the catheter technique, is further enhanced by the fact that angiographic changes caused by an arterial embolus may be discreet and as such difficult to observe

thought to be due to the toxicity of the contrast medium In two additional cases spasm occurred around the tip of the catheter without development of neurologic signs

A series consisting of 853 carotid and 118 vertebral angiographies performed with the catheter technique was reported by AMUNDSEN et coll (1963) They recorded severe complications attributed to angiography in only three cases In an additional fifteen cases major accidents occurred during the post-angiographic period However, according to the authors these could not be attributed to the angiographic procedure No embolization occurred in their series ZATZ & IANNONE (1966) described three cases with embolization complicating cerebral angiography, in one of these a catheter with side holes was used In all three cases neurologic symptoms developed in relation to the injection of the contrast medium

An embolus may be directly seen at angiography as a filling defect within the lumen of an artery or as a complete occlusion of the vessel In connection with catheterization it will probably occur in small arterial branches The experimental observations of LUESSENHOP et coll (1962) suggested that these branches usually belong to the Sylvian group The presence of an occlusion may also be evident as local slowing down of the passage of contrast medium or by the presence of a collateral circulation These signs may be present without simultaneous registration of the site of occlusion The same applies to the local accumulation of contrast medium during the capillary phase and the early filling of a local vein, the known signs of an arterial lesion (CRONQVIST & LAROCHE 1967)

According to our experience, dilatation of the artery peripheral to the site of the embolus is a common and important angiographic finding Whenever widening of a local vessel is seen, there will be reason for a careful study of the films in order to confirm or exclude partial occlusion in the central part of that vessel As ZATZ et coll (1965, 1966) pointed out "the finding of multiple small occlusions in different vessels at the onset of a complication" is suggestive of arterial embolization *The diagnosis of an embolus is definite when the defect caused by* the clot at angiography is seen to be migrating within the lumen of an artery Further proof is present when a normal angiogram immediately precedes or follows the examination demonstrating the lesion In the last-mentioned spontaneous lysis, i e rapid disappearance of an occlusion or an arterial filling defect, has taken place, a factor in favour of the diagnosis of an embolus The diagnosis will be further strengthened by the appearance of new neurologic signs These may be severe, with loss of important functions depending upon the size of the artery and the region affected They may also, however, be very slight and revealed only by close observation of the patient during the procedure There were even in our series two cases which presented no neurologic signs whatsoever despite the

marked circulatory disturbances evident in the angiograms The signs may persist but judging from the present series they appear to be mainly transitory in character In some of the cases they actually passed off so fast that only the constant observation of the patient during angiography revealed their occurrence Slow regression of symptoms was noted in only one case, although complete return to normal was delayed until a week after the incident

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Because of this, constant and thorough observation of the patient during and after an angiographic study is important. Furthermore we want to stress the diagnostic importance of the indirect signs of vascular occlusion, i e. slowing of local circulation, collateral circulation or dilatation of a partially occluded vessel as observed in some of our cases.

## SUMMARY

Seven cases of embolization during cerebral angiography are described Continuous infusion of saline and, in cases in which more than one vessel is to be studied, a fresh catheter for each procedure may lessen the risk The value in the routine use of macrodex is diminished by the large amount needed

## ZUSAMMENFASSUNG

Es wird uber sieben Falle von Gehirnembolie wahrend cerebraler Angiographie berichtet *Andauernde Infusion mit Salzlosungen und Katheterwechsel, falls mehrere Gefasse katheterisiert werden*, mogen wohl das Risiko der Embolie vermindern Die routinemassige Anwendungen von Makrodex ist praktisch erschwert, weil besonders grosse Mengen notig sind

## RÉSUMÉ

Description de sept cas d embolie au cours d'angiographie cérébrale La perfusion continue de sérum salé physiologique, et dans les cas où il faut étudier plusieurs vaisseaux, l'utilisation d'un cathéter different pour chaque angiographie, peuvent diminuer le risque La nécessité d'utiliser de grandes quantités de macrodex limite son intérêt dans la pratique courante

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FROM THE ORTHOPEDIC CLINIC, GAVLE GENERAL HOSPITAL (DIRECTOR O LINDAHL), AND DEPARTMENT OF DIAGNOSTIC RADIOLOGY, ESKILSTUNA GENERAL HOSPITAL (DIRECTOR H IDBOHRN), SWEDEN

# ROENTGENOLOGIC ANGULATION MEASUREMENT IN SUPRACONDYLAR FRACTURES OF THE FEMUR

by

O LINDAHL and A MOVIN

An important problem in the treatment of fractures, especially of those of the long bones, is the determination of any incorrect angulation that may persist after reduction The position of the fracture may usually be judged with the conventional roentgen technique, with projections in two planes at right angles to each other, parallel to the length of the bone An evaluation of the third plane—a possible rotatory malposition—is more difficult to obtain with the ordinary technique, and examiners usually content themselves with an estimation of indirect roentgen signs in combination with the clinical assessment

If the fracture is situated close to the joint, its position is sometimes difficult to determine with the ordinary examination in the two 'simple longitudinal planes Supracondylar fractures of the elbow and the femur may be cited as examples Because of the absence of readily definable longitudinal surfaces at the articular ends of the bones, determination of the position of the peripheral fragment is more or less impossible KEATS et coll (1966), in an exhaustive survey, gave exact reference planes and methods for angle estimation for most of the large joints of the body, but just the regions mentioned above were omitted The position of the femoral condyles in relation to the long axis of the femur (genu vara, genu valga) is readily defined in the frontal plane, but no method has been given for assessing a possible malposition in the sagittal plane

The present authors, when carrying out roentgenologic and clinical studies of knee joint function (LINDAHL & MOVIN 1967), found that a structure in the

Submitted for publication 1 April 1969




Fig 1 Lateral views of knee joints with reference lines traced for angulation measurements a) Arrow indicates a depression in the anterior surface of the lateral femoral condyle b) Knee joint with a supracondylar fracture of the femur angle 3° (in the sound knee 38°) c) Same as in (b) but with an angle of 36° (in the sound knee 39°)

femur close to the knee joint, not previously considered in these connections, may be used as a basis for a relatively exact evaluation of angular deformities in the sagittal plane This structure is the plane formed by the upper demarcation surface of the intercondylar fossa towards the femur and which, in the lateral projection, is depicted as a straight line BLUMENSAAT (1938) used this line only for evaluating the position of the patella, and mentioned no values for angles in relation to the long axis of the femur HULTEN (1929) also observed this plane, and stated that in order to gain an 'Einblick' into the intercondylar groove the direction of the central ray should be approximately 50° from the normal, perpendicular a p projection

BRATTSTROM (1964) considered that BLUMENSAAT s line was not of much value in the assessment of the patella alta as the angle between this line and the long axis of the femur varies considerably Variations ranging from 27 to 60° occurred in 200 knee joints of men, he made no mention of the roentgenographic technique, nor of the age distribution in the material As the knees which we had studied roentgenographically for other reasons (LINDAHL & MOVIN 1967) did not seem to show any appreciable variations, and as the difference between the right and the left sides, in particular, was small, it was considered of interest to investigate these conditions in a larger series

*Material and Methods* A series of 200 normal knee joints (100 subjects with

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If the fracture is situated close to the joint, its position is sometimes difficult to determine with the ordinary examination in the two 'simple' longitudinal planes. Supracondylar fractures of the elbow and the femur may be cited as examples. Because of the absence of readily definable longitudinal surfaces at the articular ends of the bones, determination of the position of the peripheral fragment is more or less impossible. KEATS et coll. (1966), in an exhaustive survey, gave exact reference planes and methods for angle estimation for most of the large joints of the body, but just the regions mentioned above were omitted. The position of the femoral condyles in relation to the long axis of the femur (genu vara, genu valga) is readily defined in the frontal plane, but no method has been given for assessing a possible malposition in the sagittal plane.

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## Results

A comparison between the right and left sides in the same patient revealed that the mean difference in the angle between the two sides was 0 2° ± 0 2°, with a maximum of 4° The angle between the two lines for the total of 200 knees was on an average 34 0° ±0 5°, ranging from 26° to 44°

A depression, or groove often occurs in the anterior outline, usually in the lateral femoral condyle (Fig 1a) We have found that with full passive extension of the knee, this depression always matches the anterior part of the tibial condyle plane and that these two structures usually fit into each other This hollow, when present serves as an indication of how far the knee can be extended, and it is probably a direct result of mechanical pressure when ends of the bones collide in the extended position

## Discussion

In addition to the difficulty of replacing the fragments and of keeping them in position it is often hard in the reduction of supracondylar fractures of the femur to judge whether any sagittal angulation between them has occurred As pain in the knee exudate or blood in the joint and changes in the position of the fragments during attempts to stretch the knee often make it impossible to obtain information about the position of the fragments by full extension of the joint, the assessment usually has to be made wholly from the roentgenologic lateral view with the knee in a more or less flexed position In this situation, the possibility of being able to determine the angle between the intercondylar plane and the long axis of the femur would seem to be of great value (Fig 1b)

The method not only helps to reveal any angulation thay may have arisen but also permits an assessment with an accuracy of a few degrees after a comparison has been made with sound knee If there is a depression as previously mentioned in the anterior outline of the femoral condyle its position may assist in the evaluation of the joint in full extension Over extension of the knee joint is possible in a fair number of cases (LINDAHL & MOVIN 1968) In such cases a corresponding flexion in the fracture is permissible — if for some reason an exact position cannot be achieved — without any risk of an extension defect arising after union, which might cause the knee to give away under weightbearing if stabilization by the quadriceps muscle is lacking

If this roentgenologic method is not used it often happen [illegible]

[illegible] may even be necessary Malposition in the direction of extension is less common but it occurs occasionally and produces a greatly

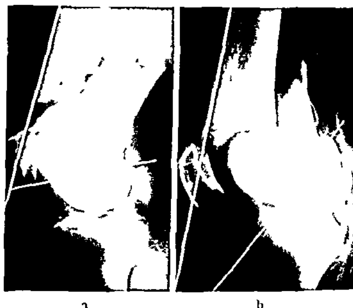



Fig 2 Reference lines traced for angulation measurements Knee joints with angle of 62° (a) (in the sound knee 37°) and with angle of 30° (b) (in the sound knee 33°)

a wide range as to age) were submitted to roentgen examination The age and sex distribution in the material is presented below

| | < 20 years | 20—50 years | > 50 years | Total |
|---|---|---|---|---|
| Men | 14 | 16 | 17 | 47 |
| Women | 17 | 9 | 27 | 53 |
| Total | 31 | 25 | 44 | 100 |

The investigation comprised patients without knee complaints who had presented themselves for disease in other regions The requirements set up for the lateral views were that the demarcations of the lateral and medial condyles of the femur, distally and posteriorly, should be parallel to a deviation between the parallelism of the two outlines not exceeding 2 mm The focal film distance was 100 cm, and the film was placed close to the lateral side of the knee joint

The plane for the floor of the intercondylar fossa (the intercondylar plane) was traced on the roentgen films, and the anterior cortical demarcation of the femoral shaft was used as the long axis of the femur This outline is usually absolutely straight within a decimeter long area above the femoral condyles, whereas the posterior femoral outline is more or less curved and the midline is sometimes difficult to define, especially in the presence of fractures, which not infrequently involve the posterior surface of the femur The angle between the anterior outline of the femur and the intercondylar plane was measured on the film (Fig 1a)

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# MOTILITY OF DIAPHRAGM IN CHILDREN WITH BRONCHIAL FOREIGN BODIES

by

GEORG THEANDER

A foreign body in a major bronchus may produce radiologic changes in the aeration of the lungs as well as in the position of the mediastinum and the diaphragm. As pointed out by JACKSON et coll. (1920) and MANGES (1922), the lung may become hyperaerated or atelectatic peripheral to the foreign body, with consequent depression or elevation, respectively, of the ipsilateral hemidiaphragm; furthermore the mediastinum may deviate away from the side with hyperaeration or towards the side with atelectasis. These changes are, however, not always sufficient to indicate the site of an *invisible foreign* body because atelectasis in one lung, *or in part of a lung*, is often accompanied by hyperaeration of the other lung, or of other parts of *the same lung*, and vice versa.

Conclusive evidence of the *site of* a foreign body may often be obtained by demonstrating a change in position of the mediastinum during respiration (MANGES 1922, KEIJSER 1930, LENK 1933, WESTERMARK 1938 and others). Like the other s

is no

it dc [illegible] side with a foreign body during inspiration (or sniffing) and towards *the opposite* side during expiration (or coughing).

Submitted for publication 11 February 1969

'over-extended' knee joint This also causes considerable discomfort, although to a lesser degree

The possibility of using the intercondylar plane for angulation assessment in connection with fractures does not seem to have received much attention Neither has it been recognized that the inter-individual variation between right and left knees is very small We can find no explanation for the greater variations in BRATTSTRÖM's material except that possibly the roentgenograms were not obtained with the object in view to elucidate the problem discussed in this paper Rotation in the long axis of the bone, and raising or lowering of the central ray in relation to the joint space, are unfortunately common occurrences at routine examinations, and they affect all angle values in the films

## SUMMARY

The angle between a plane through the roof of the intercondylar fossa and the long axis of the femur was measured in roentgen films taken with the central ray perpendicular to the sagittal plane The mean value for this angle was 34 0° ± 0 5° with a range of from 26° to 44° When the right and left sides were compared in the individual patients the mean difference in the angle was found to be 0 2° ± 0 2°

## ZUSAMMENFASSUNG

An Röntgenaufnahmen des Knies mit dem Zentralstrahl perpendikular zur Sagittalebene wurde der Winkel zwischen der Längsachse des Femurs und einer Ebene durch das Dach der Fossa intercondylaris gemessen Es ergab sich ein Mittelwert von 34° ± 0 5° mit einer Streuung von 26° bis 44° Ein Vergleich beider Seiten zeigte Unterschiede von 0 2° ± 0 2°

## RÉSUMÉ

Les auteurs ont mesuré l angle que font un plan passant par le toit de l échancrure intercondylienne et l axe longitudinal du fémur, sur des films pris avec un rayon central perpendiculaire au plan sagittal La valeur moyenne de cet angle est de 34 0° ± 0 5° avec un intervalle de 26° à 44° Quand on compare les côtés droit et gauche d un même sujet la différence moyenne de ces angles est de 0 2° ± 0 2°

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Table 1

*Twenty three children with a verified foreign body in a major bronchus*

| Case | Sex | Age | Foreign body | Site of foreign body | Interval | Conventional film pairs | | Cine films | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | I | II | I | II |
| 1 | ♂ | 4 y | Metal screw | RMB | 2 w | — | - | — | — |
| 2 | ♀ | 1 y | Metal tube | RMB | 5 w | 1 | 1 | — | — |
| 3 | ♀ | 9 m | Maize corn | RMB | 1 d | 2 | 2 | — | — |
| 4 | ♂ | 2 y | Piece of apple | RMB | 1 d | 1 | 1 | — | — |
| 5 | ♀ | 2 y | Piece of peanut | RMB | 1 d | 1 | 2 | 1 | — |
| 6 | ♀ | 11/2 y | Piece of wood | RMB | 4 w | — | 2 | 1 | 1 |
| 7 | ♀ | 2 y | Piece of nut | RMLB | <1 d | 1 | 1 | — | 1 |
| 8 | ♂ | 1 y | Piece of carrot | RMLB | <1 d | 2 | 1 | — | — |
| 9 | ♀ | 4 y | Leg of clock | RLLB | <1 d | — | — | — | — |
| 10 | ♂ | 5 y | Spiral spring | RLLB | <1 d | 1 | 1 | — | — |
| 11 | ♂ | 10 y | Piece of apple | RLLB | <1 d | 1 | 2 | — | — |
| 12 | ♀ | 4 m | Metal wire | LMB | <1 d | — | — | — | — |
| 13 | ♀ | 3 y | Pin | LMB | <1 d | — | — | — | — |
| 14 | ♂ | 10 m | Tack | LMB | <1 d | — | — | — | — |
| 15 | ♂ | 11/2 y | Tack | LMB | <1 d? | 1 | 1 | — | — |
| 16 | ♂ | 31/2 y | Piece of carrot | LMB | <1 d | 2 | 1 | — | — |
| 17 | ♂ | 2 y | Piece of peanut | LMB | <1 d | — | 3 | 1 | — |
| 18 | ♂ | 11/2 y | Piece of nut | LMB | 1 w | 1 | 1 | 1 | — |
| 19 | ♀ | 1 y | Head of thistle | LULB | <1 d | 4 | 1 | 1 | — |
| 20 | ♀ | 2 y | Pin | LB and lung tissue | ? | 1 | — | — | — |
| 21 | ♀ | 11/2 y | Pin | LLLB | <1 d | — | — | — | — |
| 22 | ♂ | 2 y | Piece of carrot | LLLB | <1 d | — | — | — | — |
| 23 | ♀ | 11/2 y | Piece of peanut | LLLB | 5 d | 1 | 2 | — | — |

Conventional film pairs and cine films before (I) and after (II) removal of f b RMB—right main bronchus RMLB—right middle lobe bronchus RLLB—right lower lobe bronchus LMB—left main bronchus LULB—left upper lobe bronchus LB—lingula bronchus, LLLB—left lower lobe bronchus

main bronchus in seven, the left upper lobe bronchus in one, and the left lower lobe bronchus in three cases In one case a metal needle had perforated the bronchial wall and was partly lodged in a lingular branch of the left upper lobe bronchus but mainly in the lung tissue The types and sites of the foreign bodies are listed in Table 1, which also gives the interval between aspiration and radiologic examination and the number of various kinds of respiratory roentgen studies performed before and after removal of the foreign body

The effect of a foreign body on the motility of the diaphragm seems to have received far less attention It is known, however, that the respiratory movements of the diaphragm may be restricted on the side where a bronchial foreign body is present This phenomenon has been recorded in many cases where foreign bodies have been aspirated and was produced experimentally by HASSLINGER & HITZENBERGER (1926) in a fluoroscopic study of the mediastinum and the diaphragm in volunteers with an olive-shaped metal body in one or more of the major bronchi MANGES (1922), who accounted for 56 cases of foreign bodies in the airways, described the fluoroscopic findings in such cases and stated that "the affected diaphragm may be lower at expiration than at inspiration HASSLINGER & HITZENBERGER, however, in the above-mentioned experiments found that neither forced respiration nor the Muller manoeuvre provoked any paradoxical movement of the diaphragm On the other hand, cases of foreign bodies in the bronchi with paradoxical movements of the ipsilateral hemidiaphragm have been reported also by ZAWADOWSKI and by LESZCZYNSKI (1958)

A complex disturbance of diaphragm movements recently observed by the present author in a child with a bronchial foreign body prompted a search for abnormalities in the position and motility of the diaphragm in previous cases of this condition The paper now presented is concerned with a report on the diaphragmatic abnormalities recorded and with their relationship, if any, to other effects of the foreign bodies

*Material and Methods* The chest films obtained in 27 children with verified foreign bodies in the bronchi were reviewed for abnormalities in the aeration of the lungs and in the position of the mediastinum and the diaphragm In one of the cases, however, the initial examination disclosed pneumomediastinum and bilateral pneumothorax, and in three others there was evidence of foreign bodies on both sides These four cases appeared unsuitable for the purpose of the investigation and were therefore excluded

Of the remaining 23 cases (eleven boys and twelve girls, aged from 9 months to 10 years) each had a single foreign body which was metal in ten and vegetable in thirteen cases (see Table 1) In the latter cases, the foreign body was not discernible and could only rarely be located by means of the air present in the bronchi, its site was however usually evident from other radiologic observations as well as from the findings at subsequent bronchoscopy In Cases 6 and 7, in which the foreign body was spontaneously removed by coughing and in which bronchoscopy was not performed, the localization had to be based upon the radiologic findings alone

The locations noted were the right main bronchus in six cases, the right middle lobe bronchus in two, the right lower lobe bronchus in three, the left

The time at which the foreign body had been aspirated was uncertain in one case and unknown in another In most cases, radiologic examination had been performed within one day of aspiration but in some cases the interval was longer and, in two cases, as much as 4 and 5 weeks

In all the cases studied, at least one conventional a.p film of the chest had been obtained In four of the ten cases with a metal foreign body and in all except three (Cases 6, 17 and 22) of the others such films had been obtained in expiration as well as in inspiration In fifteen cases, similar pairs of films had been obtained at least once after removal of the foreign body All examinations also included a lateral view of the chest Cineradiography had been performed during forced respiration in six cases (in the above-mentioned Cases 6 and 17 and two others before, in one case after, and in one both before and after removal of the foreign body) A total of 53 conventional a p film pairs or cine films were available from the twenty three cases reviewed (Table 1) These were studied for respiratory changes of the lungs, mediastinum and diaphragm In some cases a description of the findings made at fluoroscopy or roentgen TV could be extracted from the record sheets

## Results

Abnormalities other than the foreign body itself were observed in seventeen of the twenty three cases studied They included changes in the aeration of various parts of the lungs displacement and respiratory movement of the mediastinum, and abnormalities in the position and respiratory movements of the diaphragm The main findings in each of these seventeen cases are specified in Table 2 Further data are summarized under the respective subheadings below and exemplified in case reports that follow

*Aeration of the lungs* appeared normal in nine of the ten cases with a metal foreign body (all except Case 15) and in one with a vegetable foreign body (Case 4) In the other thirteen cases abnormal aeration was evident at least in the lung — or in the part of a lung — that corresponded to the bronchus harbouring the foreign body (see Table 2) This lung, or part of the lung, had evidence of atelectasis in four cases, hyperaeration in eight, and a combination of both in one case (Case 3) It usually underwent little or no respiratory variation in aeration In one patient (Case 19) however, who had been studied repeatedly before removal of the foreign body, it initially presented signs of relative atelectasis after inspiration but slight hyperaeration after expiration, whereas 3 days later it was definitely atelectatic in all phases of respiration

Abnormal aeration was frequently also evident in locations other than that

**Table 2**

*Main abnormalities in seventeen out of twenty-three children with bronchial foreign bodies*

| Case | Site of foreign body | Change in aeration | Inspiratory movement of | |
|---|---|---|---|---|
| | | | Mediastinum | Diaphragm |
| 2 | RMB | 0 | 0 | ↑ |
| 3 | RMB | A(H)* | ← | ↓ |
| 4 | RMB | 0 | ← | ↓ |
| 5 | RMB | H | ← | ↑ |
| 6 | RMB | H | ← | ↓↑ |
| 7 | RMLB | A | ← | ↓ |
| 8 | RMLB | A | ← | ↓ |
| 10 | RLLB | 0 | 0 | ↑ |
| 11 | RLLB | H | ← | ↓ |
| 15 | LMB | H | → | ↑ |
| 16 | LMB | H | → | ↓ |
| 17 | LMB | H | → | ↓↑ |
| 18 | LMB | H | → | ↓ |
| 19 | LULB | (A)<br>A } ** | →<br>0 | ↓<br>↑ |
| 20 | LB and lung tissue | 0 | 0 | ↑ |
| 22 | LLLB | H | Not examined | |
| 23 | LLLB | A | → | ↓ |

A — atelectasis, H — hyperaeration of lung tissue supplied by bronchus with foreign body Broken arrow indicates restricted excursion *A in two lobes and H in one lobe **Examinations at 3 day intervals, progression of A



Fig 1 Case 2 Metal tube in right main bronchus in inspiration (a) and expiration (b) Inverted movement of the right hemidiaphragm

hemidiaphragm during one and the same phase of respiration These complex disturbances, which are described in more detail in the reports on Cases 6 and 17, were demonstrated in cine films but were not detectable in conventional pairs of roentgenograms and may thus have been present also in cases not studied by the former method

All disturbances observed in the motility of the diaphragm were found to occur on the side with a foreign body, and no definite abnormality of the opposite hemidiaphragm was seen in any case The anomalous movements appeared largely independent of the actual position of the foreign bodies in the bronchi and presented no obvious relationship to the aeration of the lungs, but the complex disturbances in motility seen in two of the cases examined with cine films occurred in both cases on a side with hyperaeration, and in each the foreign body was lodged in a main bronchus Restricted or inverted movements, on the other hand, were present in cases with apparently normal aeration as well as in some of those with atelectasis or hyperaeration in the ipsilateral lung (see Table 2)

Repeat examinations of Case 19 before removal of the foreign body indicated that the movements of the diaphragm were normal on the first occasion but were inverted 3 days later This change in motility coincided with progression of the atelectasis peripheral to the foreign body, which was lodged in the left upper lobe bronchus, and with disappearance of respiratory movements of the mediastinum

All examinations performed after removal of the foreign bodies indicated that abnormalities previously observed in aeration and in the position and motility of the mediastinum and diaphragm had disappeared, except that, in some cases,

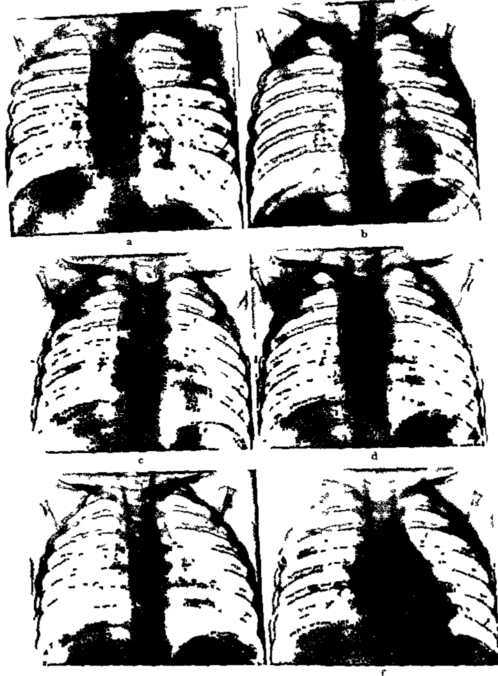
supplied by the bronchus with a foreign body. Atelectasis of an entire lung was regularly accompanied by hyperaeration on the other side, whereas hyperaeration of one lung was not always associated with any visible atelectasis on the other side. Atelectasis or hyperaeration of part of a lung was sometimes associated with *obvious hyperaeration or atelectasis*, respectively, in other parts of the same lung and, occasionally, in the other lung. During respiration the aeration was usually seen to vary in the lung tissue not supplied by the bronchus that had a foreign body.

The *mediastinum* appeared normal in position in nine of the ten cases in which neither atelectasis nor hyperaeration was observed. However, respiratory studies had been performed in only three of these ten cases, and in one of them (Case 4) inspiration was accompanied by a shift of the mediastinum towards the side with the foreign body.

Of the thirteen cases with demonstrable atelectasis or hyperaeration, or with a combination of both, respiratory studies had been performed in all except Case 22 and had consistently revealed shift of the mediastinum during respiration. In some cases the mediastinum was displaced laterally throughout the respiratory cycle and then towards a side with atelectasis, in others it resumed its normal position or was even shifted towards the opposite side in inspiration or expiration. The direction of the shift was independent of the distribution of atelectasis and hyperaeration but, as expected, during the inspiratory phase the shift was always directed towards the side with a foreign body (see Table 2). In one case (Case 19) examined repeatedly, a respiratory shift of the mediastinum was observed on the first occasion but not on a following one, despite the progression of the atelectasis caused by the foreign body.

The *diaphragm* on the same side as the foreign body was elevated or depressed in all cases with atelectasis or hyperaeration, respectively, of the entire ipsilateral lung and in some with only limited changes in aeration. The respiratory movements of the diaphragm could be evaluated in sixteen cases: they appeared normal in five and anomalous in eleven cases. The abnormalities included restricted excursions (9 cases), inverted movements (6 cases), and complex disturbances of motility (2 cases).

The criteria used in the classification of the movements of the diaphragm were as follows. Respiratory excursions were classed as restricted if they were unquestionably smaller than normal, obviously smaller than at re-examination after removal of the foreign body, or confined to only part of the diaphragm. The movement was regarded as inverted if the diaphragm was at a higher level in inspiration than in expiration. The term complex disturbance was used to denote the combined occurrence of upward and downward movements of a




F g 2 Case 5 P ece of peanut in r ght ma n bronchus (a) and (b) 1 day after its removal (c) and (d) 1? days after its removal (e) and (f) in inspiration (left) and expiration (right) Hyperaerat on of the right lung and med ast nal sh ft are seen in (a) and (b) and inverted movement of right hemidiaphragm in (a) (b) (e) and (f)

minor residual atelectasis persisted for a few days Case 5 was examined twice after bronchoscopic removal of a foreign body that had caused ipsilateral hyper aeration with displacement of the mediastinum and inverted excursion of the diaphragm The findings were normal the day after operation but 11 days later inverted respiratory movements of the diaphragm had recurred

## Case reports

*Case 2* A girl, aged 1 year, who had had repeated bouts of coughing for 5 weeks Aspiration of a piece of a toy was considered likely Radiologic examination revealed a thin metal tube with an inner diameter of 3 mm in the right main bronchus one end of the tube was flanged and had an outer diameter of 7 mm A p chest films obtained in inspiration and expiration disclosed no abnormality in the aeration of the lungs and no obvious displacement of the mediastinum but revealed inverted respiratory excursion of the right hemi diaphragm (Fig 1)

The following day the foreign body was removed by bronchoscopy through an incision in the trachea Radiologic re examination one day later indicated slight mediastinal emphysema but otherwise nothing abnormal The further postoperative course was uneventful

*Comments* The films taken in inspiration and expiration had in this case also been obtained in different phases of the cardiac cycle and recorded marked differences in the width of the mediastinum and size of the heart It is therefore uncertain whether a slight inspiratory shift of the mediastinum towards the right side occurred or not The respiratory movements of the diaphragm were small on both sides, as compared with those of the ribs, but they were obviously inverted on the right side

*Case 5* A girl aged 2 years who was thought to have aspirated peanuts and had had attacks of coughing, was admitted for examination the following day Physical examination revealed reduction of the breath sounds on the right side Roentgenography of the chest demonstrated no foreign body but revealed hyperaeration of the left lung This was most obvious in expiration The mediastinum was slightly displaced to the right in inspiration and to the left in expiration The respiratory excursions of the diaphragm were less on the right than on the left side and the level of the right hemidiaphragm in inspiration was higher than in expiration (Fig 2, a and b) Cineradiography during respiration confirmed these findings and indicated that the medial part of the right hemidiaphragm moved upwards during part of the inspiratory phase A diagnosis of foreign body in the right main bronchus was made and at bronchoscopy the following day a piece of a peanut was removed from this bronchus

Chest films obtained the day after bronchoscopy recorded normal aeration of both lungs constant and normal position of the mediastinum and normal position of the diaphragm both in inspiration and expiration (Fig 2 c and d) Radiologic examination 11 days later however unexpectedly revealed anomalous motility of the diaphragm Chest films in different phases of respiration disclosed that one hemidiaphragm moved upwards as the other moved downwards (Fig 2 e and f) and fluoroscopy during forced respiration demonstrated that the inverted movements occurred on the right side Despite this recurrence of abnormal motility of the diaphragm the patient appeared healthy and no further radiologic examination was performed

*Comments* The amplitude of the respiratory excursions of both hemidiaphragms as well as that of the ribs was greater before than after removal of the foreign body The width of



Fig 4 Case 6 Sequence of cine films (20 frames/second) Complex disturbance of motility of right hemidiaphragm during forced inspiration

slope of the diaphragm decreased and the surface again became arcuate During this final period of inspiration no movement of the mediastinum was visible

A diagnosis of foreign body in the right main bronchus was made The following day a pea sized piece of wood was coughed up Chest films one day later disclosed no abnormality (Fig 3b) and examination by roentgen TV and cine films no longer demonstrated any abnormal movement of the mediastinum or diaphragm Re examination was performed again 4 weeks later, also with normal findings

*Case 17* A boy, aged 2 years, who had had an attack of coughing while eating peanuts, was admitted for radiologic examination the same day No foreign body was seen but the a p chest [illegible]
to the [illegible]
reveale[illegible] expiration the
level of the diaphragm was high on both sides, though higher on the right than on the left side Normal downward movement of the right hemidiaphragm on inspiration was recorded The left hemidiaphragm initially also moved downwards, though less markedly than the right, but during a brief later period of inspiration its downward excursion was interrupted by rapid elevation of its medial part During a final and still briefer period of inspiration this elevation was followed by a marked downward movement which brought the hemidiaphragm down to its lowermost level

A diagnosis of foreign body in the left main bronchus was made, and at bronchoscopy the same day a piece of a peanut was removed from it Radiologic re examination, including chest films in inspiration and expiration, 1, 3 and 15 days later indicated nothing abnormal

*Case 19* A girl aged 1 year, admitted with probable aspiration of a foreign body, had been coughing for more than an hour with several bouts of marked dyspnoea Physical ex-

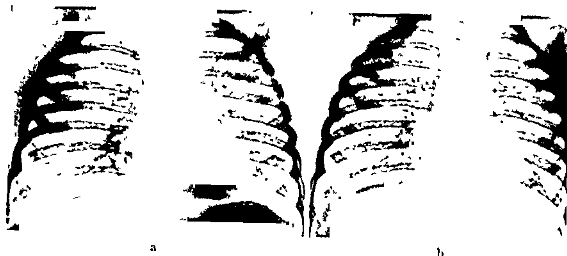


Fig 3 Case 6 Expectoration of piece of wood, before (a) and 1 day after (b) Hyperaeration of right lung with expansion of right hemithorax, displacement of mediastinum to the left and depression and flattening of the right hemidiaphragm in (a)

the chest and the slope of the ribs were equal in the films taken in inspiration and expiration at the final examination, in spite of a marked respiratory change in position of the diaphragm The available conventional films alone were thus sufficient to reveal the inverted movements of the diaphragm but not to demonstrate whether they occurred on the right or left side No explanation can be offered for the recurrence of abnormal motility of the diaphragm in this exceptional case

*Case 6* A girl, aged 18 months, who had had recurrent bouts of coughing for 4 weeks the initial attack having lasted for an hour Physical examination of the chest revealed reduced breath sounds, prolonged expiration and sibilant rales over the base of the right lung Chest films in inspiration disclosed no foreign body but demonstrated hyperaeration of the right lung, with marked expansion of the right side of the chest, slight displacement of the mediastinum to the left, and flattening and depression of the right hemidiaphragm (Fig 3a) No conventional film in full expiration was obtained but the patient was examined by roentgen TV and cine film during forced respiration (crying) Inspiratory shifting of the mediastinum towards the right side and a complex disturbance in the motility of the right hemidiaphragm were recorded The motility of the left side of the diaphragm appeared normal

The abnormal motility of the right hemidiaphragm is illustarted in Fig 4, which presents an inspiratory sequence of cine film frames taken at a rate of 20 frames/second At the beginning of inspiration the medial part of the hemidiaphragm moved rapidly upwards for a brief period, after which the lateral part began to move downwards The former movement preceded the rightward shift of the mediastinum, which commenced simultaneously with the downward movement of the lateral part of the diaphragm As a result of these combined excursions the laterad slope of the entire hemidiaphragm increased and its previously arcuate appearance became slightly biarcuate The medial part of the hemidiaphragm then remained steady while the lateral part continued its downward movement and the mediastinum moved slightly further to the right However, at the end of inspiration the entire hemidiaphragm moved upwards, the lateral part more than the medial part so that the

amination revealed nothing abnormal, and no foreign body was visible in the chest films but the radiologic examination which included a cine film study of the chest during forced respiration suggested abnormal aeration of the left upper lobe There was no change in aeration in this lobe during respiration which therefore appeared relatively atelectatic in full inspiration and slightly hyperaerated in expiration During inspiration the mediastinum particularly the upper part moved considerably towards the left side The left hemidiaphragm performed somewhat smaller respiratory excursions than the right but was situated at a lower level both in inspiration and expiration (Fig 5, a and b) A diagnosis of foreign body in the left upper lobe bronchus was made

The symptoms rapidly subsided but on radiologic re examination, which was performed twice the same day, the abnormal signs persisted Bronchoscopy was carried out the following day but revealed nothing abnormal Two days later radiologic examination, including fluoroscopy during forced respiration, was again performed The left upper lobe was then definitely atelectatic throughout the respiratory cycle The mediastinum was displaced to the left but no longer moved during respiration The respiratory excursions of the diaphragm were not so great as previously but had clearly become inverted on the left side As before, the left hemidiaphragm was at a lower level than the right in full expiration but both were at the same level in inspiration (Fig 5, c and d)

The following day bronchoscopy was repeated and this time a head of a thistle was removed from the left upper lobe bronchus Radiologic re examination of the chest a few hours later disclosed nothing abnormal Both hemidiaphragms were at almost the same level and their respiratory excursions were equal (Fig 5 e and f)

## Discussion

The respiratory movements of the diaphragm have been radiologically investigated by many authors, and several kinds of anomalous motility are on record, including restricted and inverted movements and various types of complex disturbances DAHM (1933), for example, in his roentgenkymographic studies of the diaphragm, observed paradoxical and pseudoparadoxical movements as well as 3 phase and 4 phase excursions, and even other varieties of respiratory movements Since the present investigation was mainly based on a review of roentgenograms, distinction could not be made between all of these types of abnormalities. The inverted movements discovered merely by comparison of chest films obtained in inspiration and expiration may, for example, have been simple paradoxical or pseudoparadoxical excursions, or they may have been part of some more complicated disturbance in motility

The various kinds of abnormal motility described by DAHM were observed in several diseases including bronchostenosis caused by bronchial carcinoma in which a brief paradoxical phase of respiratory movement of the diaphragm appeared not only on the same side as the tumour but sometimes on the opposite side as well Bronchostenosis caused by a foreign body does not seem to have been among the conditions investigated by DAHM

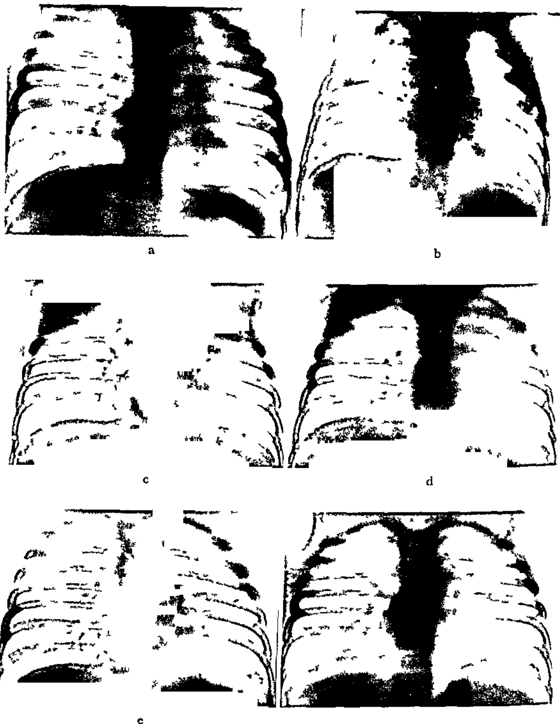



Fig 5 Case 19 Head of thistle in left upper lobe bronchus 4 days before (a) and (b) 1 day before (c) and (d) and a few hours after removal (e) and (f) in inspiration (left) and expiration (right) Mediastinal shift in (a) and (b) atelectasis of left upper lobe in (c) and (d) left hemidaphragm lower than right in (a), (b) and (d) its excursion is less than that of the right in (a) and (b) and inverted in (c) and (d)

aeration was seen in only one (Case 15) of the ten cases in which the foreign body was metallic, and that respiratory studies, performed in four (Cases 2, 10, 15 and 20) of these ten cases, revealed inverted movements of the diaphragm regularly but in only one a respiratory shift of the mediastinum It should be observed that in Case 20, in which inverted movement of the diaphragm but neither abnormal aeration nor any shift of the mediastinum were demonstrated, the foreign body was a metal needle lodged mainly in the lung tissue and only to a minor extent in a bronchus

The independence observed between the effects of bronchial foreign bodies on the diaphragm and the effects on the aeration of the lungs and the mediastinum suggests that the abnormal motility of the diaphragm associated with foreign bodies in the bronchi may not be directly related to the bronchostenosis itself Inverted movements of the diaphragm are known to occur also in various pathologic conditions other than bronchostenosis, such as after injury to the phrenic nerve The passive respiratory movements of a completely paralytic hemidiaphragm are inverted and tend to be accompanied by shifting of the mediastinum This shift differs from that in bronchostenosis in that it is directed towards the normal side during inspiration, but it is usually only slight and may easily be prevented or modified by co-existing disease (STEWART & GHISELIN 1939) Concomitant bronchostenosis and paralysis of the phrenic nerve on the same side would thus have antagonising effects on the mediastinum, the net result of which might produce no respiratory shift of the mediastinum at all or a shift that would be less marked than in either of these conditions separately but probably similar in direction to that produced by bronchostenosis alone

It is an interesting possibility that a foreign body in a major bronchus may be accompanied by reflex inhibition of the innervation of the ipsilateral hemidiaphragm This would modify the effect of the associated bronchostenosis on the mediastinum, it would thereby serve as a protective mechanism reducing the risk of severe circulatory disturbance inherent in any marked respiratory shifting of the mediastinum It would also help to explain the occurrence of inverted movement of the diaphragm in cases of bronchial foreign bodies without any vi [illegible] view it is note [illegible] piratory studies before removal of the foreign body recorded no shift of the mediastinum belonged to those with inverted movements of the diaphragm It should also be recalled that in Case 19 progression of atelectasis peripheral to the foreign body was accompanied, not by any increase, but by the disappearance of respiratory shifting of the mediastinum, and that this was associated with a change from normal to inverted excursions of the diaphragm These observations would be plausibly explained by the protective mechanism suggested above and seem to

Various deviations from the usual pattern of motility of the diaphragm have also been recorded in apparently healthy subjects. The amplitude of the excursions during forced respiration is far from constant and may normally differ from one side to the other. BELBENOIT (1958) described a presumably healthy male in whom the movements of the diaphragm on voluntary coughing were occasionally inverted. The inversion sometimes affected the right and sometimes the left hemidiaphragm. According to ALEXANDER (1966), unilateral paradoxical movements of the diaphragm may be provoked by sniffing in 6 % of normal subjects, and then more often on the right than on the left side.

Such occasional normal deviations of motility might have been erroneously classified as abnormal in the present investigation, but this seems unlikely since in all cases re-examined after removal of the foreign body any previously demonstrated abnormality in motility proved to have disappeared. The invariable localization of the anomalous movements to the ipsilateral hemidiaphragm provides further evidence that these were truly abnormal and due to the presence of a foreign body in the airways.

The various types of abnormal motility of the diaphragm recorded in bronchostenosis have usually been attributed to a disturbed relationship between the changes in intrapleural and intraabdominal pressures during respiration. This relationship would seem likely to become disturbed particularly in bronchostenosis severe enough to produce atelectasis or hyperaeration of the entire ipsilateral lung. MANGES (1922), who seems to have been the first to have reported inverted movements of the diaphragm in cases of bronchial foreign bodies, also held the opinion that such movements occurred 'in severe cases'. In the present investigation, however, the motility of the diaphragm was largely independent of the aeration of the lungs. While invariably ipsilateral to the foreign body, inverted movements of the diaphragm were in two cases seen on a side with hyperaeration and, in one case on a side with atelectasis, however, they also occurred in three cases without any visible abnormality of aeration. On the other hand, they were not seen in all of the cases with marked atelectasis or hyperaeration.

HASSLINGER & HITZENBERGER (1926), in their aforementioned experiments with volunteers, occluded various bronchi with olive-shaped metal bodies that were either solid or perforated by longitudinal canals of different sizes. They observed no effect of the occlusion on the lungs, mediastinum or diaphragm unless the foreign body had reduced the lumen of a major bronchus by two-thirds or more, and the earliest effect discovered was a respiratory shift of the mediastinum. It is difficult to assess the degree of obstruction caused by the foreign bodies in the present cases because it may have been aggravated by stagnation of secretions and swelling of the mucosa, but it is noteworthy that abnormal

## ZUSAMMENFASSUNG

Es wurde bei einer Analyse von Rontgenaufnahmen und Cinefilmen in 23 Fällen von Bronchialfremdkorpern bei Kindern beobachtet, dass verschiedene Bewegungsabnormitaten der gleichseitigen Zwerchfellkuppe in 11 von den 16 Fallen auftraten, in denen die Atmungsbewegungen genau untersucht wurden Die diagnostische Bedeutung solcher Bewegungsabnormitaten konnte durch weitere Beobachtungen in diesen elf Fällen erleuchtet werden

## RÉSUMÉ

[illegible]

a ete faite Les constatations faites dans ces onze cas montre l interêt diagnostique de ces mouvements respiratoires anormaux

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lend further support to the assumption that foreign bodies in the bronchi may exert part of their effect on respiratory dynamics by causing reflex inhibition of the innervation of the diaphragm

The abnormal movements of the diaphragm recorded in cases of bronchial foreign bodies may be diagnostically important, particularly in two respects As pointed out by DAHM (1933), inverted excursions of one hemidiaphragm may cause uncertainty as to whether a chest film obtained has been taken in inspiration or expiration and may therefore make it difficult to ascertain which side moves anomalously In his opinion the slope of the ribs and the width of the chest in such cases are reliable indicators permitting radiologic distinction between the different phases of respiration This view is supported by some observations made in the present series, as exemplified in Case 2 (Fig 1) In Case 5, however, the slope of the ribs and the width of the chest were on one occasion equal in the films taken in both inspiration and expiration (Fig 2, e and f) These films, though revealing inverted movement of the diaphragm, were thus insufficient to demonstrate whether the right or the left hemidiaphragm moved abnormally, and *continuous observation of the respiratory movements* proved necessary to make sure that the inverted excursions occurred on the right side but not on the left

Abnormal movements of the diaphragm may on the other hand help to reveal the existence or the site of a foreign body in the airways The present series included three cases (*Cases 2, 10 and 20*) *in which this sign was demonstrated* in the absence of any visible abnormality in the aeration of the lungs and without any shift of the mediastinum The foreign bodies themselves were readily seen in these cases but if they had not been metallic the abnormal excursions of the diaphragm would, at least at the time of the examination, have been the only radiologic clue to the correct diagnosis

**Acknowledgement**

Financial support by a grant from the Swedish National Association against Heart and Chest Diseases is gratefully acknowledged

## SUMMARY

*A review of conventional and cine films of the chest* in 23 cases of foreign bodies in the bronchi in children revealed various types of abnormal movements of the ipsilateral hemidiaphragm in 11 of 16 cases in which respiratory studies had been performed Observations made in these eleven cases illustrated the diagnostic significance of such abnormal respiratory movements



Fig 1 Case 1 Continuous gas filling in the intestinal tract there is a lobulated soft tissue mass in the right iliac fossa encroaching upon the gas-filled colon but leaving a channel free for the gas to communicate with the caecal pole

ditions (KJELLEN 1955, KJELLEN et coll 1957, BELL & STEYN 1962) Thickening of the Peyer s patches has been observed in a proportion of cases of mesenteric adenitis coming to operation (AIRD 1945) The thickened Peyer s patches can lead to intussusception, which in due course will cause intestinal blood loss. On the other hand, sloughing of diseased Peyer s patches can lead to intestinal blood loss without intussusception (HAJDU 1955)

In the author s experience the diagnosis of enlarged mesenteric lymph nodes, to the exclusion of intussusception, can often be made by conventional roentgen examination of the abdomen In a number of cases it could also be made as a reasonable alternative to the diagnosis of acute appendicitis, though not to the exclusion of the latter, since radiographically silent, pre perforative appendicitis and mesenteric adenitis may co-exist

For the past 16 years nearly all infants and children who presented with abdominal pain at our Paediatric Unit had, on admission, three antero-posterior films taken of the abdomen (1) supine, (2) erect and (3) left lateral recumbent The total skin dose in the central axis of the beam varied between 0 15 and 0 27 R according to the age of the patients During this time, 47 cases of intussusception and 72 cases of mesenteric adenitis were studied by the author in the latter group a definite diagnosis of mesenteric adenitis could be made in 30 cases

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# MESENTERIC ADENITIS IN CHILDHOOD SIMULATING INTUSSUSCEPTION

by

NICHOLAS HAJDU

Acute non-specific mesenteric adenitis is a common disease in children It is a frequent source of error in the diagnosis of the acute abdomen AIRD, writing from the Surgical Unit of the Royal Edinburgh Hospital for Sick Children in 1945, reported that in a single year he found, on laparatomy, 37 cases suffering from non-specific mesenteric adenitis, compared with 83 suffering from acute appendicitis The difficulty of distinguishing between mesenteric adenitis and acute appendicitis has been emphasized by many authors Since objective proof of mesenteric adenitis short of laparatomy could not be obtained, surgeons tended to operate rather than to rely upon unsupported clinical evidence (JONES 1969)

The fact that acute mesenteric adenitis can closely simulate intussusception has received less attention Yet pallor, colicky abdominal pain, a palpable mass in the right iliac fossa and admixture of blood to the stools are common to both Furthermore, both intussusception and mesenteric adenitis tend to occur in small epidemics and the one is often etiologically related to the other (ROSS & POTTER 1961, GARDNER et coll 1962) The causative role of adenovirus 1, 2, 3, 5 and 6, and very occasionally E C H O 7 and 9 appears well verified in both con

Part of this paper was read at the Reunion Internationale de Radiologie Pediatrique in Paris May 1963 Submitted for publication 15 April 1969

intestinal gas in the conventional position of the caecum. This is the visual equivalent of Dance's sign, i.e. the feeling of emptiness in the right iliac fossa on rectal examination.

3. The mass of the intussusception, which may be seen as an ovoid soft tissue mass. It may bulge into the colonic gas so as to produce a cup-shaped termination of the latter. It causes a gap between the gas of the small intestine and the gas in the large bowel, i.e. a discontinuity of gas filling. In the left lateral recumbent position the colonic gas fails to rise into the caecum and ascending colon.

When the intussusceptum is loose, signs of obstruction are absent. One has to rely chiefly upon the signs referable to the mass of the intussusception, listed under (3).

When shock is severe, gas is scant or completely absent. The radiologist is faced with the ominous picture of a 'grey abdomen'.

*Mesenteric adenitis.* The diagnosis of mesenteric adenitis is based upon positive findings, i.e. the visibility of enlarged lymph nodes, and negative ones, i.e. the absence of signs of intussusception.

The positive signs are as follows. In the supine and left lateral recumbent positions the mass of enlarged lymph nodes can appear as a lobulated soft tissue mass, particularly against a background of common meteorism (Fig. 1). Even smaller lymph nodes can produce pressure defects upon the medial wall of the caecum and ascending colon, particularly in left lateral recumbency (Fig. 2). These defects are extrinsic, often multiple, and involve the proximal third of the colon, whereas the filling defect caused by the head of the intussusceptum is intrinsic, single, and usually found in the middle third of the colon. An important feature was noted in left lateral recumbency: the enlarged lymph nodes could be seen through the gas content of the caecum and ascending colon in the shape of rounded masses, on the same principle as the kidneys can be seen through the gas-inflated stomach (Fig. 3). Usually both effects are present, i.e. the lymph nodes partly indent the gas of the colon and are partly overlapped by the same (Fig. 4). This double characteristic helps to distinguish them from scybala which produce intraluminal filling defects.

The negative signs are as follows. When the patient is placed into the left lateral recumbent position, the colonic gas rises into the caecum, i.e. there is no intussusceptum to interfere with the postural shift of colonic gas. In infants and small children, where meteorism is the rule, it is usually obvious that there is no discontinuity of gas filling between the small and large intestine. N...

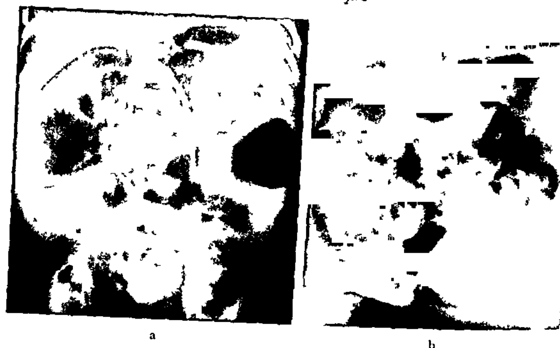


Fig 2 Case 2 a) *Supine film* showing a fair amount of gas in the transverse colon b) In left lateral recumbent position the gas *moved* into the caecum and ascending colon Multiple extrinsic pressure defects are *seen on the* medial contour of the bowel caused by rounded masses of soft tissue

through direct *demonstration* of the enlarged lymph nodes In the remaining 42 cases, a tentative diagnosis was made on the basis that the findings in conventional roentgenograms of the abdomen were contrary *to the accepted signs of* intussusception Hence *it seems appropriate* in this context to give a grief review of these signs

*Intussusception* The signs depend upon the degree of patency of the central canal and upon the severity *of the associated* shock Most of these have been described *in the* literature (SCHATZKI 1939, HELLMER 1948, FRIMANN-DAHL *1951*, MIDDLEMISS 1955, and others) The author s contribution is confined to observations in the left lateral recumbent position

The intussusception can be very tight, moderately tight *or loose* When very tight, *it produces signs* of complete, low, small-intestinal obstruction When moderately tight, the roentgenologic signs fall into three groups

1 Those representing partial obstruction, i e one or two fluid levels usually situated in the right iliac fossa

2 Shortening of the colon The most consistent sign is the *presence of small*

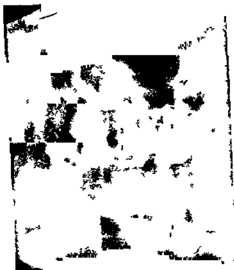


Fig 4 Case 4 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon the gas column in the caecum and ascending colon partly overlaps and is partly indented by rounded masses of soft tissue

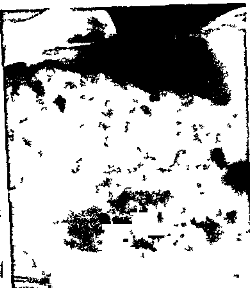


Fig 5 Case 5 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon there are several enlarged lymph nodes which partly indent the colonic gas and are partly seen through it

*Case 2* Boy aged 6 months with history and clinical signs on admission consistent with intussusception The radiologic examination led to the diagnosis of mesenteric adenitis (Fig 2) and no treatment was given The child was discharged home free of symptoms 3 days later

*Case 3* Boy aged 4 years was admitted with a 3 day history of abdominal pain first centred round the umbilicus but later located in the right iliac fossa The pain was coming and going and colicky in character The boy did not vomit the bowels were rather loose He looked pale there were a few submandibular lymph nodes and on deep palpation a tender mass could be felt deep in the right iliac fossa

Survey films of the abdomen are shown in Fig 3 A large lymph node was seen in left lateral recumbency The child was discharged home the following day Occult blood which was present on admission persisted for 14 days and full recovery took one month

*Case 4* Boy aged 4 years who 4 days before admission began to have abdominal pain which became worse during the last 24 hours The pain lasted a few seconds he screamed out with pain and doubled up Clinical examination revealed a soft abdomen and a palpable descending colon but no masses were felt The boy was kept under observation for 24 hours he was still having central abdominal colicky pain vomited once and had faeces in rectum Intussusception was thought probable




Fig 3 Case 3 a) Supine film showing no characteristic feature b) In left lateral recumbency the gas shifted from the transverse into the ascending colon a large mesenteric lymph node is now clearly seen through the gas

trinsic filling defects the diagnosis is mesenteric adenitis, when the gas does not rise to the caecum or when there is a single and intrinsic filling defect the diagnosis is intussusception

The following case reports are presented to exemplify our findings

## Illustrative cases

*Case 1* Girl aged 4 months Screaming attacks followed by slightly blood stained constipated stools started 2 days before admission she once vomited dark brownish material The screaming continued all the night before admission On examination there was a doubtful mass in the right iliac fossa (Several members of the family had had a sore throat during the previous month )

Roentgen examination (Fig 1) revealed continuous gas filling in the intestinal tract A lobulated soft tissue mass was seen in the right iliac fossa it encroached upon the gas filled colon but left a lateral channel free for the gas to communicate with the caecal pole

Despite the definite radiologic evidence of mesenteric adenitis the clinicians decided to have a laparatomy performed This revealed large mesenteric lymph nodes of the non specific variety Blood was visible in the lumen of the small intestine but no pressure mark of past intussusception was observed Some of the Peyer s patches were thickened and it was assumed that one must have sloughed away and caused the bleeding



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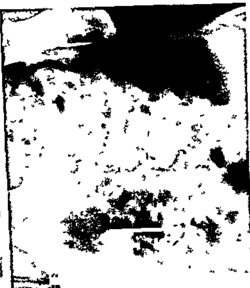


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Films taken in supine and erect positions were unremarkable The roentgenogram obtained in left lateral recumbency is presented in Fig 4 The colonic gas had shifted into the proximal colon, the caecal pole was filled with gas, which rendered intussusception unlikely *The gas in the caecum and ascending colon partly overlapped and was partly indented by* rounded soft tissue masses No treatment was given, apart from mild laxatives The boy's condition improved and he was discharged home after 48 hours

*Case 5* Boy, aged 1 year and 9 months, who had been well until the morning of admission During the day he had repeated attacks of abdominal pain which doubled him up and which were followed by vomiting He had no diarrhoea but refused to eat The boy was crying and was apprehensive during the examination, he had a soft abdomen and a doubtful mass of glands in the right iliac fossa and his temperature was raised The roentgen film in supine position was of no interest In left lateral recumbency the colonic gas shifted into the proximal colon Several enlarged lymph nodes were observed which were partly encroached upon and partly overlapped by the gas in the caecum and the ascending colon (Fig 5)

## Discussions

The author's first observation was made in 1953 (see Case 1) In the subsequent years there was an average of 4 to 5 cases per year Each patient was *referred under the clinical suspicion of intussusception and the diagnosis* of mesenteric adenitis was made primarily on the basis of survey films of the abdomen The diagnosis in each case was then discussed with the clinicians and if any doubt remained a diagnostic barium enema was performed The need for the latter became smaller as the clinicians gained confidence in the radiographic diagnosis but it is still of the order of one in six It is greater in those cases in which the radiographic diagnosis is based merely on the negative signs of mesenteric adenitis, i e those excluding intussusception, than in those which give positive proof of enlarged lymph nodes

No case of intussusception was missed but there was one child, aged 11 months, in whom a diagnostic error might have occurred An ileo ileal intussusception had progressed to the hepatic flexure without invaginating the caecum The intussusceptum formed a finger-thick filling defect in a wide caecum and ascending colon which were fully distended by gas Another child, aged one and a half years, was diagnosed as mesenteric adenitis and treated expectantly A month later he was re-admitted with the typical picture of intussusception At the subsequent *operation both conditions were found to co-exist*

All cases had in common that there was either a pyrexial upper respiratory illness 5 days to 2 weeks before onset of abdominal pain or that other members of the family had feverish colds, pharyngitis or malaise during the preceding period Stool examinations by culture were done as a routine but in none of the cases were pathogenic bacteria found The cases occur when adenovirus in-

fections are common Virus studies were made in the hospital population at the relevant time, in some of the cases diagnosed as mesenteric adenitis and in some of the contacts, they showed increased incidence of adenovirus types 1, 2 and 5

## SUMMARY

The radiographic appearances of acute non specific mesenteric adenitis are presented and the differential diagnosis with particular reference to intussusception is discussed

## ZUSAMMENFASSUNG

Die röntgenologische Erscheinungen bei akuter nicht spezifischer Mesenterial Drüsenentzündung werden beschrieben und die Differentialdiagnosis besonders mit Hinsicht auf Intussusception wird diskutiert

## RÉSUMÉ

Description des aspects radiographiques de l'adénite mesentérique aiguë non spécifique et discussion du diagnostic différentiel, en particulier avec l'invagination intestinale de l'enfant

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# HISTOLOGIC STAINING OF CONTRAST-FILLED BLOOD VESSELS IN MICROANGIOGRAPHED TISSUES

by

MARTTI KORMANO

Microangiography is valuable in research and has been recently used to an increasing extent. It is usually performed by filling the microvascular system of tissues with a fine-grained barium sulphate suspension.

Histologic preparations from tissues that have been microangiographed enable routine histologic studies of the material to be made. Microradiography and histology together afford valuable information on the relationship between microscopic structures and the appearances of the capillary bed in the microangiogram. Unfortunately, identification of all capillaries is not achieved by the standard microangiographic methods now available (LUNDSKOG, BRÅNEMARK & LINDSTRÖM 1968). Although microradiograms well depict the filled vessels, even three-dimensionally (BELLMAN 1953), only a rough estimate of the number and location of unfilled vessels is obtained. A histologic study is often helpful although careful examination of the distribution of filled capillaries is laborious because of the low contrast of barium sulphate grains in small capillary cross-sections. Certain routine histologic staining methods were therefore tried for identification of small filled blood vessels in microangiographed tissues of the testis and epididymis. Histochemical methods used for indicating acid mucopolysaccarides were also studied.

Submitted for publication 27 March 1969



Fig 1 Haematoxylin eosin staining of a 10 μ section of a microangiographed rat testis The barium sulphate in the capillaries is unstained × 800



Fig 2 Haematoxylin eosin staining of section of microangiographed 20 day-old rat testis Filled capillaries visible with high power objective due to birefringent properties of barium sulphate grains × 2 080



Fig 3 PAS haematoxylin staining of adult rat testis The barium sulphate in the capillaries is weakly purple although this does not call forth the pattern of the filled capillaries × 80



Fig 4 The same testis as in fig 3 but the section was stained with 0 5 % Alcian blue at pH 2 6 for 10 minutes Filled blood vessels intensely stained and some stain also in the testis tissue × 80




Fig 5 A 10 μ testis section stained with 0 1 % Alcian blue at pH 2 6 for 10 minutes a) The filled blood vessels are selectively stained × 80 b) Detail of (a) The staining of contrast medium in the capillaries is intense as compared with the background × 120

*Material and Methods* Male Sprague-Dawley rats were injected with barium sulphate 10 % (Micropaque, Damancy & Co Ltd) The injection and tissue processing were performed according to the standard procedure described in detail elsewhere (KORMANO 1967, 1968), using 4 % buffered formaldehyde for fixation After paraffin embedding, 10 μ histologic sections were cut from the testes and epididymides and stained by the following methods haematoxylin eosin, periodic acid-Schiff-haematoxylin, Weigert-van Gieson, Cresyl violet, Bodian's silver impregnation, toluidine blue, Astrablau and Alcian blue The relative differential staining intensity of the tissue and barium sulphate grains was studied microscopically

## Results

The barium sulphate granules remained unstained in the haematoxylin eosin sections (Fig 1) Identification of blood vessels down to arteriolar size was easy but capillary filling was often difficult to confirm The location of the contrast medium had to be identified with a high-power objective and by taking advantage of the birefringent properties of Micropaque granules (Fig 2) A low-power objective failed to reveal clearly the number and distribution of filled capillaries in a tissue section On the other hand, an oil immersion objective



Fig 6 PAS haematoxylin staining of section of microangiographed rat epididymis Only the largest blood vessels are easily identifiable × 210



Fig 7 Alcian blue 0 1 % staining at pH 2 6 for 10 minutes of section of same organ as in fig 6 The smallest filled capillaries are identifiable × 210

indicated that the microscopic structure of the capillary walls was well preserved and easily identifiable

The periodic acid Schiff method stained the barium sulphate granules weakly purple (Fig 3) The staining intensity was however low and generally less than that of the surrounding tissue Identification of the pattern of filled capillaries was therefore less easy than in HE-stained sections. Blood vessel walls were sharply defined and the weak staining of the contrast medium did not interfere with the high-power observation

Weigert van Gieson stain, especially suitable for connective tissue components within vascular walls, failed to stain the barium sulphate No staining or any other advantage was obtained by using Cresyl violet, Toluidine blue or Bodian's silver impregnation Astrablau staining for 10 to 30 minutes with 0 1 or 0 5 % at pH 0 2 to 10 0 enabled a differentiation to be made between the barium sulphate grains and the tissue However, the strong blue staining of mast cell granules (BLOOM & KELLY 1960) and, on the other hand, variable intensity of the staining of the contrast medium was found to limit the value of this stain as a method of detecting filled capillaries

In preliminary experiments, 0,5 % Alcian blue (Alcian blue 8GX, Allied Chemical, Lot No 0365218, C I No 74240) stained the Micropaque granules

within blood vessels blue (Fig. 4). Epithelial cells of the epididymis and the contents of the epididymal duct were also heavily stained as compared with other cells. Because Alcian blue staining was the most promising of the techniques tested, its properties were examined more closely at different pH values from 2.6 to 10.0 and dye concentrations of 0.1 and 0.5 % of the staining bath. The tissue was intensely and diffusely stained with 0.5 % Alcian blue. The relative staining intensity of the barium sulphate grains also increased in the alkaline range but diffuse staining disturbed the differentiation between the content of the blood vessels and the tissue. At pH 2.6, little diffusion of the stain occurred but staining of tissue still occurred. The stain had some affinity to the walls of the blood vessels, and this in connection with the relative unsharpness of the general colour level rendered greater magnifications impracticable. Alcian blue staining at acid pH proved however a practicable means of detecting all the filled blood vessels, independent of size. By reducing the dye concentration to 0.1 % at pH 2.6, selective staining of a barium sulphate-filled vascular bed was obtained (Fig. 5). A time of 10 minutes was found to be sufficient, longer times causing greater colouring of the background.

This procedure was found to result in selective staining of barium sulphate grains in testis tissue (Fig. 5a) and a very good differentiation of filled epididymal blood vessels was achieved in spite of staining of the epididymal duct epithelium (Figs. 6 and 7).

## Discussion

The weak contrast of the barium sulphate grains in histologic sections is not a disadvantage for it does not disturb the general study of cellular structures. This may be to the good if extravasation is apt to occur, as is often the case in microangiography of pathologic tissues (RUBIN 1966). However, if the number of filled capillaries, or the general capillary density of the microangiographed specimen are to be studied, detection of the small undilated branches may be difficult. An attempt was made to overcome this disadvantage by adding Indian ink to the barium sulphate suspension (KARPPINEN & MYLLARNIEMI 1967). This addition led however to a poor microscopic demonstration of the innermost layers of the blood vessels, and it may in case of leakage completely destroy the histologic picture. The entry of Indian ink particles into a given capillary also does not necessarily mean that the latter is filled by the contrast medium, as the latter has a different particle size and a higher specific gravity. The method of specific staining of barium-filled blood vessels would therefore seem to be ideal for this kind of work.

Alcian blue, a cationic or 'basic', orthochromatic copper phthalocyanine dye,

groups (SINGER 1952, SCOTT,
in the barium sulphate particles
medium easily distinguishable

WAGNER & SHAPIRO (1957) have demonstrated that an obvious loss of polysaccharide specificity of Alcian blue occurs at as low a pH as 2.8. In spite of the staining of the barium sulphate even at higher pH ranges, the increase in background staining in the present application of the method also proved disturbing. The result seems to some extent to depend on the type of fixation. Staining with Alcian blue fails to meet the needs of a careful histologic examination of the tissue itself. It is however a simple and practicable method to use with routine staining procedures when information on the extent and localisation of capillary filling is required in microangiographed tissue embedded in paraffin.

## Acknowledgement

The investigation was aided by a grant from the P. O. Klingendahl Foundation.

## SUMMARY

The staining characteristics of intravascular barium sulphate grains were studied in his
... Alcian blue was found to stain the barium
...ectively and intensely

## ZUSAMMENFASSUNG

Es wurden Versuche angestellt, um die Farbebereitschaft von Bariumsulfatkörnchen in
...
angiographischen Schnitten hervorstechen.

## RÉSUMÉ

Les caractéristiques de coloration des grains de sulfate de baryum intravasculaires ont été étudiées sur des coupes histologiques de tissus microangiographiés. Le bleu alcian colore sélectivement les granules de sulfate de baryum dans les tissus fixés en formaline et inclus en paraffine et assez intensément pour faciliter l'identification des structures microvasculaires injectées.

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# ANGIOGRAPHIC DEMONSTRATION OF RUPTURE OF THE SPLEEN

by

BO LUNDSTROM

Clinical diagnosis of rupture of the spleen may often entail considerable difficulties. As a number of publications during the last decade have indicated the value of angiography to support this diagnosis there would appear to be good reason for reporting two cases in which the angiographic findings deviated somewhat from those previously published.

The first case of splenic rupture diagnosed angiographically was published in 1957 by NORELL who injected contrast medium into the aorta by means of a catheter inserted via the femoral artery. ÖDMAN seems to have been the first to use selective angiography of the coeliac artery for diagnosing rupture of the spleen. OLIN & EKMAN were early in publishing three cases angiographically diagnosed, all with operative verification. Accounts of a few cases have been given by BOIJSEN & OLIN, POLLARD et coll., NEBESAR et coll., BAUM et coll. and ROSCH. In these earlier publications, avascular areas in the spleen caused by the rupture itself or an associated haematoma, were given as the most important angiographic findings. BAUM et coll. also observed rapid circulation.

A larger number of cases examined angiographically of splenic rupture have

Submitted for publication 7 May 1969.

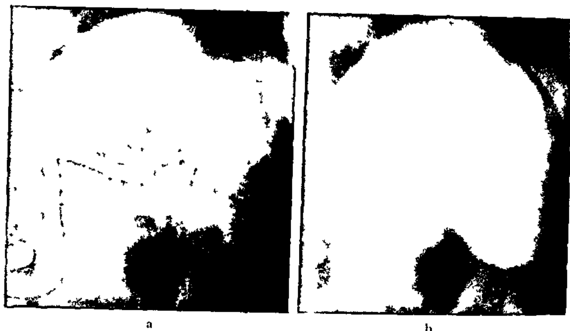



Fig 1 Normal splenic angiography of the arterial phase (a), and the venous phase (b)

been reported during the last two years (AAKHUS & ENGE, LOVE et coll, BERK & WHOLEY) These support the view that the detection of avascular areas surrounded by displaced vessels represents an important diagnostic finding, even if it is not constant The most typical angiographically demonstrable change would seem to be an accumulation of contrast medium in small extravasations with blurred definition BERK & WHOLEY intimated that this 'mottled effect' might be due to aggregation of contrast medium in the sinusoids of the spleen This was noted by AAKHUS & ENGE and by LOVE et coll as well as by BERK & WHOLEY in 37 of their combined total of 42 cases In these three publications, rapid circulation (i e the veins soon become filled with contrast medium) was said to be common and angiographically demonstrable in a good half of the cases (24 out of 42 cases) FONTAINE et coll published 6 cases with operative verification The angiographic findings were, however, not analysed in detail in their paper

It has long been known that cystic cavities may appear in the spleen after rupture but no filling of such cysts in the course of angiography seems to have been described No case has been published of a false positive or a false negative diagnosis of splenic rupture at angiography with the typical findings mentioned above

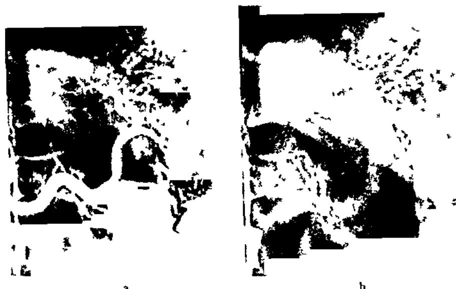


Fig 2 Rupture of the spleen (Case 1) in the arterial phase (a) and early venous phase (b) Numerous small extravasations in the supply area of the upper arterial branch the splenic veins are filled sooner from the upper than from the lower part of the spleen, no angiographic changes in the lower pole

## Case reports

*Case 1* A 19 year old woman previously healthy fainted some hours after moderate trauma to the left lower part of the thorax but was without symptoms after 24 hours Pain partly of an intermittent nature first appeared in the right lower abdomen The patient was admitted four days after the accident Her general condition was good there was tenderness to palpation partly in the right lower abdomen and partly under the left rib arch Haemoglobin 9 9 g % white blood corpuscles 5 300/mm$^3$ and blood pressure 140/85 Survey films of the abdomen disclosed a moderate amount of free fluid but otherwise no changes Since the possibility of rupture of the spleen could not be excluded selective angiography of the coeliac artery was performed

*Angiography* Fig 2) showed the splenic artery to be divided into two main branches The supply area of the lower branch was normal (cf Fig 1) The arteries in the supply area of the other branch were somewhat stretched The parenchyma of this part of the spleen was irregularly contrast filled and a large number of small irregular cavities were contrast filled The filling of the veins occurred somewhat earlier from the upper part than from the lower part of the spleen The radiologic diagnosis was rupture of the spleen

Laparotomy revealed more than half a litre of blood in the abdominal cavity There was longitudinal rupture of the spleen from the hilum towards its upper pole Histologic examination of the spleen demonstrated haemorrhages in connection with the rupture but otherwise no changes



a b

Fig 3 Rupture of the spleen (Case 2), in the arterial phase (a) and the venous phase (b) Several cavities in the upper part of the spleen are filled and emptied at different rates with early venous filling from one of them (→), an avascular area is present in the ventral part of the spleen, no angiographic changes in the lower pole

*Case 2* A 23-year-old man, previously healthy, was admitted following a traffic accident with bone fractures and concussion On the patient's arrival, when he was fully conscious, no abdominal symptoms were noted After several days the patient began to complain of atypical pain in the left side of the abdomen, this was partly intermittent in nature and was aggravated by coughing, urination and defecation The symptoms gradually increased, and three weeks after the injury increased tenderness to palpation under the left rib arch was noted Some days later selective angiography of the coeliac artery was carried out to eliminate splenic rupture of the spleen

*Angiography* (Fig 3), which was performed 26 days after the trauma, showed no changes in the lower third of the spleen (cf Fig 1), in other parts of the spleen the larger arterial branches were normal in appearance The contours of the parenchyma were irregular and noticeably less dense in the upper part of the spleen than in the lower pole Several large, well-defined cavities in the upper and central parts of the spleen filled at different rates, and emptied at different times A vein leading from one of these cavities filled in the early arterial phase A large avascular area lay in the central region The radiologic diagnosis was splenic rupture

Laparatomy disclosed half a litre of stale blood in the abdominal cavity The spleen was enlarged with a longitudinal rupture laterally One large and several smaller subcapsular haematomas were present Splenectomy was performed The histologic examination indicated partly healed rupture of the spleen a and several haematomas and parenchymal necroses No other changes were observed

## Discussion

The some 70 cases of angiographically diagnosed cases of rupture of the spleen so far published have provided certain valuable diagnostic criteria As far as can be judged, the most constant pathognomonic finding is the demonstration of numerous small irregular extravasations This sign has been observed in practically all cases where angiography has been carried out less than 4 days after the trauma, but has been absent in the few cases with older ruptures Other important angiographically demonstrable signs of rupture are rapid circulation and the presence of avascular areas

Rapid circulation was observed in some part of the spleen in the two present cases Different parts of the spleen had completely different angiographic appearances but in each case the caudal part of the spleen was angiographically normal

Small irregular extravasations of contrast medium of the type previously described were observed in the cranial part of the spleen in Case 1 LOVE et coll have published a similar case The spleen is divided into two arterial supply areas between which there are no anastomoses a larger upper anterior part and a smaller lower posterior part It would seem reasonable to assume that only the upper anterior part of the spleen was involved in the rupture in Case 1, and was the reason for the different angiographic appearances in the two parts of the organ Large well-defined cavities in the upper part of the spleen were filled in Case 2 and from some of these the contrast medium passed quickly into the veins as in arterio-venous aneurysms No similar case has previously been published It is likely that only the cranial part of the spleen was involved in the rupture in the present case

## Addendum in proofs

Another case, similar to Case 2, has been observed since the preparation of the manuscript Angiography of the coeliac artery was performed in a 43 year-old man with multiple injuries a few hours after trauma Some irregular cavities in the upper part of the spleen were contrast filled, from these cavities the splenic vein filled in the early arterial phase The appearance was similar to traumatic arterio-venous fistulas elsewhere in the body, there was no mottling A large splenic rupture in the upper part of the spleen was seen at operation

## SUMMARY

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the from
the from
[illegible] described as typical of rupture

## ZUSAMMENFASSUNG

Es wird uber zwei Fälle von angiographischer Diagnose von Milzruptur berichtet Neben den bekannten Zeichen der Milzruptur zeigten beide Fälle Varianten der bisher wohl bekannten angiographischen Befunde

## RÉSUMÉ

Présentation de deux cas de rupture de la rate diagnostiquée par angiographie Ces deux cas presentaient des signes angiographiques assez differents de ceux qui ont ete decrits comme typiques de la rupture de la rate

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# EFFECT ON ERYTHROCYTES OF LARGE DOSES OF CONTRAST MEDIUM IN CLINICAL ANGIOCARDIOGRAPHY

by

LARS BJORK

Evidence has gathered through the years that a large part of the side effects of modern contrast media is directly correlated to the hyperosmolarity of these products. As the red blood cells are exposed to the highest concentration of the contrast medium on rapid intracardiac or aortic injection, these are obviously the cells that may be expected to incur damage, particularly on repeat examinations. It has been indicated that such damage occurs, by in vitro studies (BERNSTEIN et coll 1964, MCINTOSH et coll 1967) and in animal experiments (BERNSTEIN et coll.). The aim of the present study has been to determine whether changes in the red blood cells may be demonstrated with standard laboratory methods, in patients in whom large quantities of highly concentrated contrast media had been injected at angiocardiography.

*Material and Methods.* The material consisted of 10 routine cardiac patients, six men and four women, aged between 41 and 56 years, subjected to angiocardiography as part of a pre operative evaluation for cardiac disease. Two were suffering from angina pectoris and the others had valvular heart disease.

Submitted for publication 19 June 1969

Unusually large quantities of contrast medium were needed in all the patients to arrive at a complete diagnosis The dose varied between 3 0 and 3 7 ml per kg body weight, divided between four or five different injections during 20 to 30 minutes All the injections were made into the left side of the heart or into the aorta The speed of injection was approximately 30 ml per second and the contrast medium used was Isopaque 350 (sodium metrizoate balanced with calcium and magnesium ions, iodine content 350 mg/ml, Nyegaard & Co A/S, Oslo)

Blood samples for the laboratory studies were drawn from catheters in the right atrium or pulmonary artery Samples were obtained immediately before the first injection of contrast medium and within 60 seconds after the last injection In addition, blood samples were obtained 24 hours after the angiocardiographic examination for determination of the haptoglobin The following determinations were made in the blood samples obtained before and after angiocardiography (1) hematocrit, (2) plasma osmolarity, (3) diameter of erythrocytes, (4) morphologic characteristics of erythrocytes, (5) osmotic resistance of red blood cells, (6) mechanical resistance of red blood cells, (7) potassium content of red blood cells, and (8) haptoglobin content of serum

## Results

A decrease in the hematocrit value after the angiocardiographies occurred in all patients, the average decrease being 16 % of the value obtained before angiocardiography, with a range of 10 to 27 % A slight but significant increase in plasma osmolarity was also recorded after angiocardiography No change could be observed in the diameter of the red blood cells, or in the mechanical or osmotic resistance of the blood cells after angiocardiography when compared with the values before angiocardiography

The number of cells with crenation was slightly increased after angiocardiography in two patients No other morphologic changes were present Also the potassium content of the blood cells was unchanged No significant change in the haptoglobin values before angiocardiography and 24 hours after angiocardiography were observed

## Discussion

With the exception of the slight increase in crenation of the red blood cells observed in two patients, the methods used in the study failed to disclose any acute or permanent damage to the red blood cells, even after injection of rel

atively large quantities of contrast medium for angiocardiography This is contrary to the findings of MCINTOSH et coll In the in vitro experiments, in which blood was exposed to a constant concentration of contrast medium, BERNSTEIN et coll observed a decrease in the red blood cell diameter, and morphologic changes in the red blood cells, both by animal experiments and in vitro tests with Biligrafin in 'clinical doses, in vitro tests with Hypaque produced however no or only minimal changes

An increase in the serum potassium, concomitant with a rapid decrease in hematocrit, was reported by MCINTOSH et coll after aortic injection of Isopaque 440 In the present investigation, no evidence of loss of potassium from the erythrocytes was found It therefore seems likely that if loss of potassium from the erythrocytes, sufficient to explain the increase in serum recorded by MCINTOSH et coll, occurs, it must be a reversible process or the potassium must be released from other cells

A considerable decrease in hematocrit occurred in all the patients, without any corresponding decrease in the red cell diameter, and with minimal changes in the morphologic appearances of the red blood cells in only two of the ten patients This means that shrinking of the erythrocytes is probably responsible only for a minor part of the change in hematocrit observed at the same time Migration of fluid from other cells or from extravascular spaces is probably largely responsible for the decrease in hematocrit

The concept that cardiography with the technique now presented fails to give rise to permanent damage to the red blood cells is in agreement with the clinical observation that hardly ever signs of hemolysis occur after angiocardiography This is also confirmed by the spectrophotometric studies of plasma in which no evidence of hemolysis was found (KLOSTER et coll 1966) On the other hand, hemolysis was recently reported in three patients following angiography (COHEN et coll 1969) Cholegrafin in vitro gave an increase both in haptoglobin and free hemoglobin, whereas Hypaque produced no definite changes (BERNSTEIN et coll )

The results of the study would appear to indicate that the red blood cells are resistant to damage by highly concentrated contrast media even when injected repeatedly in large quantities However, the methods used possess sources of error and may be too insensitive to reveal minor changes The possibility must also be considered that damaged erythrocytes may have been removed from the blood or pooled, and consequently may not have reached the sampling site Acute changes occurring during the first seconds after injection, when the concentration of contrast medium in the blood is high, may have been overlooked in the study If such acute changes occur, they must be transient and fail to produce any appreciable permanent damage

## SUMMARY

The diameter, morphology, osmotic resistance, mechanical resistance and potassium content of the red blood cells as well as the haptoglobin content of the serum were studied in ten patients before and after angiocardiography with large doses of contrast medium. No differences were recorded with the exception of a slight increase in the number of crenated red cells in two patients.

## ZUSAMMENFASSUNG

An zehn Patienten, die erhebliche Dosen von Kontrastmittel während angiographischen *Untersuchungen erhalten* hatten, wurden die Erythrocyten bezüglich ihres Durchmessers, ihrer Morphologie, ihrer osmotischen und mechanischen Resistenz sowie ihres Kaliumgehaltes vor und nach der Injektion überprüft. Es zeigten sich keinerlei bedeutsame Unterschiede; nur die Anzahl von Zellen mit gezähnten Rändern war in zwei Fällen leicht vermehrt.

## RÉSUMÉ

L'auteur a étudié le diamètre, la morphologie, la résistance osmotique, la résistance mécanique et la teneur en potassium des érythrocytes ainsi que la teneur du sérum en haptoglobine chez 10 sujets avant et après angiocardiographie faite avec de fortes doses de moyen *de contraste. Il n'a pas noté de différence si ce n'est une légère élévation du nombre* des érythrocytes crénelés chez deux sujets.


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# Book reviews

CEREBRAL ANGIOGRAPHY By H Krayenbuhl and M Yaşargil 401 pages and 524 illustrations Butterworths, London 1968 Price 18 £ 10 Sh

The second edition of this well known textbook on cerebral angiography has been translated into the English language with the text revised and newly gained experiences incorporated As in the original German edition the illustrations are excellent and their number is overwhelming

A chapter deals with the authors technique for angiography Contrary to the practice of the reviewer the authors recommend puncture of the common carotid artery as a normal procedure and selective puncture for special purposes they favour direct puncture of the vertebral artery

A comprehensive and extensive survey of the anatomy of the cerebral vessels and their normal variations is most valuable and occupies nearly a quarter of the book Some of the work deals with the angiographic signs in space-occupying lesions which have been divided into non specific displacement syndromes and specific localization syndromes Displacement syndromes are tabulated and discussed from pathologic and angiographic viewpoints, various forms of herniations and localizations of expanding lesions being differentiated The topographic diagnosis of supra and infratentorial tumours are considered in a special chapter, copiously illustrated with roentgen films as well as drawings

The authors emphasize that the pathologic diagnosis of intracranial tumours is best made by serial angiography in which the vascularity of the mass as well as the disturbed circulation within the tumour can be studied The differences in appearance between gliomas meningiomas and metastatic tumours are well documentated and angiographic signs separating different forms of gliomas, as well as detailed investigation of meningiomas are described Disturbances in the circulation as evident from cerebral angiography, not only in connection with different kinds of tumour but also as a part of disease of the cerebral vessels are discussed Modern concepts of angiographic investigations of ischemic lesions are however given less attention than the classical aspects of angiography, i e tumours malformations traumatic incidences A chapter deals with the physiology and pathology of the cerebral circulation and also includes remarks on collateral circulations in different conditions

The book includes an extensive bibliography the vast number of references being arranged in relation to each chapter but collected at the end of the book. There is also an authors' index as well as a reliable subject index both of which should prove useful The book represents a good reference source and should be valuable for looking up anatomical variations and anomalies and as well as for gathering information on expanding lesions and their locations within the brain

*Bengt Liliequist*

ZONOGRAPHY—NARROW-ANGLE TOMOGRAPHY By D Westra 82 pages, 38 figures and 58 references Excerpta Medica Foundation, Amsterdam 1966 Price. 18 DFL

The term 'focal plane' is utilized for the tomographically produced image plane in the introductory chapter dealing with the fundamentals of tomography This is unfortunate because the object and its projected 'space image' is always three-dimensional and the recording film can be arranged in any desired plane and orientation The term 'focal plane' refers exclusively to optical systems in which at infinity, for instance, a focal plane exists. The existence of the 'space image' discussed by MARSTRANDER has been ignored

It is claimed that narrow-angle tomography may give 'more information than ordinary tomography' The information to be obtained from tomography is distributed in the numerous cuts, which must always be studied together Three-dimensional topographic information will then be obtained It is wrong to believe that a single tomogram constitutes an examination

A narrow-angle tomogram is a compromise and may cover in a defective way what ordinary tomograms may provide As the tomographic angle is varied continuously, films may be obtained down to those with no angle at all and a summarily fixed projection, the ordinary radiogram Alteration of the tomographic motion pattern regarding shape and size produces varying tomographic effects A reduction of the angle primarily means reduced tomographic effect so that the layers are in the form of a summation A true tomogram representing one layer cannot be compared with one 'composed' of several layers

The author overlooks the 'space image' and its immense number of possibilities in the fundamental description of tomography The law of the tangent and the image formation is discussed with references to ZIEDSES DES PLANTES and EDHOLM The expression 'focal depth' is introduced here and for reasons already mentioned ought to be avoided

Misunderstanding in the presentation of points of difference is obvious Different object borders cannot be demonstrated either by tomography or zonography Tomography is a more selective method and zonography includes more detail, not different detail Zonography is a superimposing of cross sections The opinions about maximum acceptable unsharpness, discussed in the thirties, have not the same value today, modern apparatus is capable of producing well defined sections at 1 mm interspacing and a so-called layer thickness of the order of a tenth of a millimeter These factors are of real importance as small objects are often of interest The demonstration of sharpness and contrast of image borders would be clarified by a drawing The experiments seem to have been made with unsuitable exposure conditions—the contrast being too low—and with a blackening indicating that the density curve would be nonlinear, a fact that might influence the conclusions In hypocycloid motion the borders always have a characteristic tendency to form double or triple contours This does not appear from the illustrative material and raises the question as to what factor has hidden it The experimental presentation is somewhat confused The expression 'integration density curve' is introduced to represent the 'shadow' of an object This is another example of the unauthorized use of scientific expressions' Density curves (H and D curves) must be exclusively retained for densitometry in photography and radiography

The definition of the tomographic image border including certain physiologic aspects and viewing distances are discussed and experiments with the latter for tomograms up to 5 meters are mentioned The discussion based on EDHOLM's work ignores the role played by photographic factors The author arrives at the conclusion that a free zone around the object is important and calculates its depth Some applications are presented, e g to the thorax, tracheobronchial system, gallbladder and kidneys Stereoscopy with zonography is mentioned

*Ove Mattsson*

DIAGNOSTIC RADIOLOGIC INSTRUMENTATION—MODULATION TRANSFER FUNCTION Edited by Robert D Moseley Jr and John H Rust 425 pages, 180 figures 23 tables and 155 references Charles C Thomas, Springfield Illinois 1965 Price 17 50 dollars

Great need exists for specification of methods for measurement of image quality A colloquium on Diagnostic Radiologic Instrumentation was held at the University of Chicago, the proceedings of which form the content of this volume

BOUWERS in presenting electronic equiqment for recording contrast transfer, mentions photographic problems He seems to accept the modulation transfer function principle although the photographic recording is nonlinear INGELSTAM in the subsequent discussion touched upon non linearities in the intensifiers for electronic reasons which might produce difficulties in applying this linear theory O'LOUGHLIN stressed the difficulties in applying modular transfer function to film screen combinations and mentioned that ROSSMAN has modified the problem and made a power spectrum, mathematically similar but dose dependent and producing other complications

TUDDENHAM considered visual physiology and instrumentation in roentgen diagnosis MORGAN discussed problems connected with quantum fluctuations and visual perception SCHOBER applied the Shannons information theory to roentgen images, its value in radiology is limited The extreme care that must be taken to avoid using it improperly is exemplified, it is only applicable to purely optical systems

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from the exposure

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well with the image quality of intensifiers and treated all parts of the chain, vignetting and internal scatter are presented MOSELEY HOLM and WILLIAMS have made a study of various camera tubes In the subsequent discussion ROSSMAN emphasized that true modular transfer function must be independent of noise and FOWLER stressed that the presentations are, because of noise not modulation transfer curves GUYOT recorded a study of factors limiting resolution and contrast in intensifiers MARHOFF and SCHOTT made an evaluation of the roent

[illegible]

ROSSMAN [illegible] been more valuable to compare Magnification in intensifiers was discussed by FEDDEMA and ZIEHLER compared various TV chains in clinical practice

This collection of papers are of considerable value, their value is further increased by the discussions which to some extent may form a substitute for readers who did not attend the meeting

*Ove Mattsson*

HISTORY AND DEVELOPMENT OF RADIOLOGY IN DENMARK 1896—1950 By P Flemming Moller 530 pages and some twenty photos and figures Nyt Nordisk Forlag Arnold Busck Copenhagen 1968 Price 78 50 DKr

The physicians who first recognized the value of the new roentgen technique and attempted to bring it into use in medical practice encountered resistance and a sceptical attitude from fellow physicians The author convincingly maintains that the odd and controversial character, J Mygge, must be regarded as the pioneer of Danish radiology After this account the author in the following chapters may be said to have borrowed his method of describing the historic development from tomography, each layer being confined to a description of the events of one year Thus the radiologic material published in Danish medical journals year by year, and consisting of original articles reports on lectures read before Danish associations and notes on articles from foreign journals thus form the main source of the material From the year 1921 material from Acta Radiologica naturally enough is also mentioned The reports are carefully worked out and information is given regarding the page on which the original article appears in the relevant journal By this method the author presents the historical material in the form of a structure in time in which the events of each individual year add up to make a whole Brief isolated reviews of past events are given only occasionally The foundation and development of the university training clinics for radiodiagnosis and radiotherapy and the creation and extension of teaching appointments are however dealt with in order

This work presents an exhaustive survey of the radiologic development that has taken place in Denmark A special complementary section containing consecutive accounts of the developments in the various fields of diagnosis (heart and lungs alimentary tract urinary tract, nervous system and so on) as well as of those in the field of radiotherapy in general would have added much to the interest It should however be added that the reader has the possibility of obtaining such information for himself by utilizing the index in which the medical diagnoses and authors cited are included

The book bears the mark of scrupulous attention to detail and in consequence has great documentary value as a retrospective account of the historical developments in medical radiology

*Folke Knutsson*

RONTGENDIAGNOSTIK DER ILIOSAKRALGELENKE UND IHRER NAHEN UMGEBUNG Von W Dihlmann 141 Abbildungen in 258 Einzeldarstellungen Georg Thieme Verlag Stuttgart 1967 Price 54 DM

Different lesions of the sacroiliac joints play a dominant role in low back pain although only too often early diagnosis is overlooked because of inferior routine roentgen examination of the lumbar spine Such an examination should always include adequate examination of the sacroiliac joints irrespective of the clinical request so that the examiner may recognise the normal variations and the early signs of pathologic processes

It is therefore a pleasure to review this excellent book dealing with the sacroiliac joints The anatomy and roentgenology of these joints are presented with excellent illustrations A chapter dealing with malformations is followed by the main chapter on inflammatory lesions of the joints naturally dominated by spondylitis ankylopoetica This condition is

called pelvospondylitis ossificans in Sweden which appears to be a more adequate term in the light of knowledge of the nature of the disease

The reviewer cannot agree with the author on die nosologische Einordnung krankhafter Iliosakralbefunde, neither with the statement that ostitis condensans may occur in man. These comments do not however reflect upon the essential value of this important chapter from the view point of roentgen diagnosis thanks to detailed descriptions of both early and late lesions superbly illustrated with roentgen films and drawings. The chapter on degenerative changes is most instructive and the last chapter on expansive lesions in the iliosacral region is noteworthy for the manner in which the diagnostic difficulties are depicted

The wide experience of the author is reflected in the text and the illustrations are of excellent quality and well chosen. The book can be warmly recommended

*S en Id n*

DAS RONTGENFERNSEHEN ...

DUNG By Prof Dr Alfre

164 pages 92 figures

Price 34 DM

The two first mentioned authors are radiologists at the University of Frankfurt am Main the third being employed at the Siemens Scientific Laboratory. This will indicate the value of the presentation of this important subject

Conventional fluoroscopy is discussed in relation to physiologic aspects and dosage. The construction of the image intensifier is described and its properties are discussed also the

... are discussed ... and subtraction by electronic means as well as stereoscopic fluoroscopy with roentgen television, image storage systems and video tape recording are all included

The use of television for various purposes in a roentgen department with arrangements to present current examinations to large audiences are exemplified. Various practical sol ...

... ologic or neurosurgical purposes. Roentgen television in connection with pediatry, oto laryngology, gynaecology and roentgen therapy is briefly mentioned

The extensive list of references (close to 300) increases the value of a book that has much to give to most radiologists

*Ove Mattsson*

DYNAMIC FACTORS IN ROENTGEN DIAGNOSIS By Elliott C Lasser With a chapter by John H Feist and a foreword by Leo Rigler 356 pages, 134 figures Williams & Wilkens Company, *Baltimore 1967 Price 12 75 dollars*

Roentgen diagnosis in the early days was founded upon anatomy and pathology and depended upon the laws of physics and geometry that produced the roentgenogram It was *something static with little regard paid* to dynamic factors Conditions have changed, not at least by the introduction of new roentgen procedures as well as by a different way of analysing the information available from the films obtained

This book initially carried the title 'Physiologic Factors underlying Roentgen Anatomic Diagnosis' This has been rephrased to indicate that radiographic examinations present either active or completed processes A wider understanding of the close relation between the roentgen and various physiologic factors may be obtained from the appreciation of meta bolic considerations, physiologic chemistry, effect of drugs and innervation and endocrine effects as well as secondary changes arising from anomalities and abnormalities in secretion Knowledge of an embryologic background leads to a better understanding of gross anomalies *Again the findings in a case of heart failure must be considered with due regard to the* dynamic conditions

The work is concentrated on certain organs The central nervous system and the urinary tract are discussed in separate chapters The effects of contrast media receive special attention and their development and chemistry are described The gastro intestinal tract is afforded considerable space, with references extending to some one hundred and twenty The basic physical and physiologic principles of the heart are considered with special reference to car diac failure The evolution of congenital abnormalities is explained, pulmonary dynamics and kymographic methods are consiered, and the biologic basis of bone roentgenology and bone metabolism is discussed in a simplified manner Diseases of bone are dealt with and attention paid to the mineral content of bone and its measurement An extensive and well illustrated differential diagnosis approach to bone changes forms an important part of the book

This work offers a valuable concentrated contribution to radiologic diagnostics of today where new aspects compared with conventional static principles are in the foreground It should prove particularly useful, say to radiologic trainees and to those engaged in teach ing

*Ove Mattsson*

ACTA RADIOLOGICA

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Vo 10 | DIAGNOSIS | 1970
Fasc 3 | | May

# ANGIOGRAPHIC DIAGNOSIS OF TUMORS ARISING FROM THE PANCREATIC ISLETS

by

ERIK BOIJSEN and LARS SAMUELSSON

The first preoperative angiographic diagnosis of a pancreatic insulin producing tumor was reported by OLSSON (1963) Since then, several reports on the value of selective angiography in the diagnosis of tumors of the islets of Langerhans have appeared

The hormone-producing neoplasms of the pancreas are usually richly vascularized and accumulate contrast medium to a higher degree than the surrounding structures Nevertheless they are frequently so small that they may escape detection even in high quality celiac and superior mesenteric angiograms A small growth embedded in the parenchyma may also escape detection at operation It is therefore of importance to establish whether a firm preoperative diagnosis of an islet cell tumor can be achieved with selective angiography

*Previous investigations* Tumors of the islets of Langerhans usually produce hormones and four distinct syndromes may develop (1) hyperinsulinism caused by beta cell tumor, (2) the Zollinger Ellison syndrome caused by an overproduction of gastrin from a non beta cell tumor, (3) a severe form of diarrhoea with

From the R [illegible] nd University Hospital Sw[illegible] the Swedish Medical Res[illegible]

[illegible] May 1969

hypokalemia probably due to an unknown hormone from a non beta cell tumor, and (4) hyperglucagonism with diabetes caused by an alpha-cell tumor

Both alpha- and beta cell neoplasms may be present without concurrent hormonal production

There are reports in the literature of 35 patients with insulin producing tumors evaluated with selective angiography of the celiac or superior mesenteric arteries (OLSSON 1963, 1965, BAUM et coll 1965, BUONOCORE et coll 1965, ROSCH 1965, ROSCH & BRET 1965, WENZ 1965, BOOKSTEIN & OBERMAN 1966, MADSEN 1966, McCONNELL et coll 1966, OLIVIER et coll 1966, SCHEININ & TALA 1966, VUORINEN & WEGELIUS 1966, HERNANDEZ & HELENON 1967, NEBESAR & POLLARD 1967, VAN VOORTHUISEN 1967, LENARDUZZI et coll 1968) Two patients had two tumors each and one patient had three tumors Fourteen tumors were located in the head, four in the body, and fifteen in the tail of the pancreas In five patients, each with one tumor, the site was not reported In one patient, who had had a previous pancreatectomy, hyperinsulinism resulted from liver metastases demonstrated by angiography Of the 33 operated tumors, 22 were recognized at angiography Of the 11 undetected growths, 2 were located in the head of the pancreas, 2 in the pancreatic body and 7 were present in the tail of the pancreas One tumor was 2 mm in diameter while the remaining ten varied in size between 10 and 30 mm

The twenty-two growths with positive angiographic findings were between 10 and 50 mm in size BOOKSTEIN & OBERMAN were unable to identify five out of seven insulin-producing tumors and were of the opinion that only 20 % of these could be demonstrated by high quality selective angiography MEANEY & BUONOCORE (1965) and MADSEN (1968) noted on the other hand that even small histologically poorly vascularized beta cell tumors could be demonstrated by angiography

Excluding the material of BOOKSTEIN & OBERMAN, thirty-two insulin producing tumors have been reported, twenty-five of which (80 %) were demonstrated at angiography It must be emphasized that five of the seven growths of BOOKSTEIN & OBERMAN were situated in the tail of the pancreas, an unusual angiographic location for beta-cell tumors In a large series insulin producing tumors occurred most frequently in the tail of the pancreas (BREIDAHL et coll 1955)

Four malignant insulin-producing tumors, all with metastases were evaluated by angiography (OLSSON 1965, ROSCH & BRET 1965, HERNANDEZ & HELENON 1967, MADSEN 1968) Two of the patients had richly vascularized metastases while small liver metastases were undetected in the other two patients

Non beta islet cell tumors producing the Zollinger—Ellison syndrome have been identified by angiography in seven patients (BOIJSEN 1965, FONTAINE et coll



Fig 1 Benign insuloma of the tail of the pancreas in a 57 year-old woman No growth was revealed at combined celiac and superior mesenteric angiography At selective splenic angiography however a 15 mm tumor could be seen close to the tail of the pancreas (arrows) There is accumulation of contrast medium in the growth but no tumor vessels can be seen

1965, Ludin et coll 1966, Clemett & Park 1967, Hernandez & Hellenon 1967, Thomas et coll 1968, Zboralske & Amberg 1968) In one of these, in whom pancreatic resection had been performed previously, local *recurrence as* well as metastases were observed Five of the ulcerogenic tumors were malignant, *with metastases* of the same type of vascularization as the malignant insulin-producing tumors, i e small richly vascularized, nodular tumors The primary growths whether malignant or benign, were all richly vascularized

One patient with a non beta cell malignant tumor and without the ulcer diathesis had profuse diarrhoea (Goulon et coll 1966) The *Zollinger—Ellison* syndrome may start with diarrhoea before the ulcerations appear Here again the rich vascularization *present in the other* non beta *cell* tumors was observed

Hyperglucagonism secondary to an alpha cell carcinoma has been observed in one patient, who had *angiography for* hepatic metastases (McGavran et coll *1966*) In this patient the primary as well as the secondary tumors were highly vascular and therefore well demonstrated at *angiography*

Non functioning islet cell carcinomas do occur (Hess 1946) *Only three* patients with a malignant *inactive* insuloma *appear to* have been stud ed angio

s p ... growths, the metastases were also similar

Previous findings at angiography of islet cell tumors have indicated that the malignant tumors are generally larger, have more abundant tumor vessels and are therefore better demonstrated than the benign beta or non beta cell tumors

hypokalemia probably due to an unknown hormone from a non beta cell tumor, and (4) hyperglucagonism with diabetes caused by an alpha cell tumor

Both alpha and beta cell neoplasms may be present without concurrent hormonal production

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Non beta islet cell tumors producing the Zollinger—Ellison syndrome have been identified by angiography in seven patients (BOIJSEN 1965, FONTAINE et coll



Fig 3 Malignant insulomas of the duodenum and of the uncinate process of the pancreas in a 59 year old woman who had been diabetic for 17 years Barium meal examination and subsequent celiac angiography disclosed a richly vascularized tumor of the duodenum At superior mesenteric angiography however the same tumor as well as a second tumor in the uncinate pancreatic process were demonstrated Displaced arteries tumor vessels and dense accumulation of contrast medium in both tumors (arrows) There were no metastases

celiac and superior mesenteric arteries while three patients had injections only into the celiac artery

In the total of eighteen patients in whom selective angiography was performed, eight insulin producing tumors were observed in seven patients Twelve of the patients were operated upon and one additional neoplasm was discovered in a patient in whom the angiographic examination was considered normal In the six patients who were not operated upon the angiograms were negative and the symptoms were either too vague or could be ascribed to other causes

Revaluation of the angiographic series in the eight patients with insulin producing tumors gave the following results The tumor not diagnosed prior to operation was a 30 mm carcinoma located in the tail of the pancreas The angiograms, with combined injection into the celiac and superior mesenteric arteries were of moderately good quality and after subtraction in retrospect slight vascular abnormalities were observed These were not however sufficient to establish a definite diagnosis The tumor could probably have been diagnosed if injection of contrast medium had been made into the splenic or hepatic arteries but this method was not in practice at that time

The remaining eight tumors were found prior to operation but on two occasions injection into the splenic and hepatic arteries was necessary to establish the diagnosis In both these patients there was a definite clinical diagnosis of an

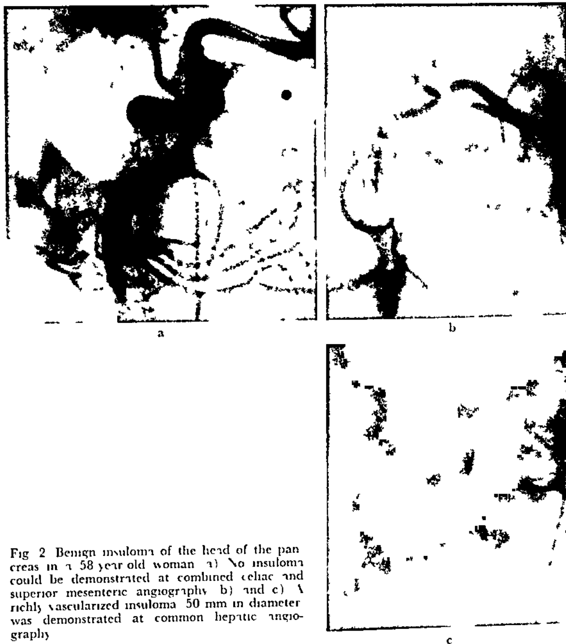



Fig 2 Benign insuloma of the head of the pancreas in a 58 year old woman a) No insuloma could be demonstrated at combined celiac and superior mesenteric angiography b) and c) A richly vascularized insuloma 50 mm in diameter was demonstrated at common hepatic angiography

## Material and Results

*Hyperinsulinism* Eighteen patients had symptoms referable to an insulin producing tumor Selective angiography was performed in all In fourteen of the patients the contrast medium was injected simultaneously into the celiac and superior mesenteric arteries, and in two patients injection into the splenic and hepatic arteries was also performed One patient had separate injections into the



Fig 5 Normal pancreas in a 51 year-old man who 30 years previously had undergone gastric resection and who for 2 years had been diabetic and had attacks of fainting Combined celiac and superior mesenteric angiography disclosed a 35 by 20 mm tumor in the pancreatic tail (arrow) No local accumulation of contrast medium but tortuous vessels Resection of the pancreatic tail revealed no tumor The abnormal findings were related to the presence of collateral circulation from the left gastroepiploic artery following ligation of the right gastroepiploic at the earlier gastric resection

One patient had a benign 20 mm neoplasm of the uncinate process, again exclusively supplied by the superior mesenteric artery (Fig 4) The tumor had the same angiographic characteristics as those previously mentioned At operation it was neither seen nor palpated, but following incision of the pancreas in the area angiographically demonstrated to be abnormal, the growth became visible and was removed

With one exception tumor vessels were observed in all patients with a preoperative diagnosis of insuloma Their extent varied but was generally greater in growths more than 20 mm in diameter Displacement of small pancreatic arteries was observed in six of the neoplasms Accumulation of contrast medium always occurred, except in the lesion not diagnosed prior to operation Venous drainage was observed in seven tumors The largest growth in this series measured 50 mm in diameter and was benign The three malignant tumors varied from 20 to 30 mm in diameter

Four tumors were located in the tail of the pancreas and four in the head of the pancreas, which included two in the uncinate process and one tumor in the duodenum

Resection of the pancreatic tail was performed in three patients who had local hypervascularization in this area at angiography but in whom no neoplasm was seen at microscopy Gastric resection had been performed previously in one of these patients, and at angiography a local network of tortuous arteries gave the



Fig 4 Benign insuloma of the uncinate process of the pancreas in a 58-year-old woman with typical signs of hyperinsulinism for 4 years Combined celiac and superior mesenteric angiography revealed a 25 by 20 mm tumor, richly vascularized and containing a dense accumulation of contrast medium The tumor at operation was found to lay in the abnormal area demonstrated at angiography

insulin-producing tumor, and this was the indication for the further angiographic procedures In one patient, the 15 by 10 mm tumor was demonstrated in the tail of the pancreas only after splenic artery injection No tumor vessels could be seen but an intense and long-lasting accumulation of contrast medium was present. Even in retrospect the growth could not be identified in high-quality combined celiac and superior mesenteric angiography (Fig 1)

The second patient also had a combined injection into the celiac and superior mesenteric arteries but the arteries of the head of the pancreas were not demonstrated because of an anomalous origin of the common hepatic artery directly from the aorta After selective injection of contrast medium into this artery, the complete blood supply of a 50 mm tumor was demonstrated (Fig 2).

Two malignant insulin-producing tumors were present in one patient One was located in the duodenum and was demonstrated by a barium meal and celiac angiography, the second was present in the uncinate process and was first demonstrated by superior mesenteric angiography (Fig 3) Both growths were malignant and their respective diameters were 20 and 25 mm, they were highly vascularized and the accumulated contrast medium remained for a long time

graphy At operation, an 8 mm benign insuloma was extirpated from the body of the pancreas Reviewing the angiographic series with the subtraction technique, a local accumulation of contrast medium was present in the body of the pancreas No tumor vessels could be identified (Fig 7).

*Non functioning tumors of the pancreatic islets* Three patients were referred for angiography because of general malaise in one patient and jaundice in the remaining two There were no signs of endocrine activity but at operation malignant insulomas were revealed in all three patients The growths were located in the head of the pancreas and were highly vascular With the exception of more tumor vessels, the angiographic appearances regarding accumulation of contrast medium and venous drainage were similar to those in tumors with endocrine activity All had metastases and these had the same characteristics as those possessing endocrine activity (Fig 8)

## Discussion

Despite the fact that several series of patients with hyperinsulinism have now been reported, with tumors demonstrable by selective angiography, the question of accuracy is still unanswered The experiences of BOOKSTEIN & OBERMAN suggest that angiography should be inadequate to diagnose insulin-producing tumors The present angiographic series, in which eight of nine insulin producing tumors were demonstrated prior to operation, permits a more optimistic view of the diagnostic value of angiography in this disease This is also in agreement with other communications, though it must be admitted that positive findings are more likely to be reported than false negatives

An explanation for the difference in the results attained in the present series compared with those of BOOKSTEIN must be sought The location of the lesion seems to be an important factor Small tumors of the pancreatic tail may more easily escape detection All the undemonstrated growths of BOOKSTEIN, larger than 10 mm in diameter, were present in the tail of the pancreas With the same angiographic technique the present authors were unable to demonstrate two out of four neoplasms Special injections in one of these patients produced the correct preoperative diagnosis Thus, if combined celiac and superior mesenteric angiography fails to demonstrate an insuloma in a patient with typical symptoms and laboratory findings of hyperinsulinism, the diagnostic procedure should be complemented with injection into the splenic artery There was reason to believe that the only growth that went undiagnosed in the series could have been demonstrated by the method The improved quality obtained after injection into the splenic artery better demonstrates small pancreatic lesions (PAUL JR et coll 1965, BOIJ



Fig 6 Normal pancreas in a 24 year old man who for 10 years had attacks ascribed to hyper insulinism Combined celiac and superior mesenteric angiography suggested insuloma of the tail of the pancreas At operation, however the pancreatic tail was resected but proved to be normal In retrospect the hypervascularization was due to the positioning of the tip of the catheter in the celiac artery from which a large amount of contrast medium was directed into the dorsal pancreatic artery

impression of malignancy, in retrospect it seemed to be caused by a collateral circulation arising as a consequence of the resection (Fig 5) There was no local accumulation of contrast medium in the area where abnormal vessels were observed The other two patients had a diffuse but marked accumulation of medium in the tail of the pancreas This resulted from inadvertent positioning of a catheter tip in the dorsal pancreatic artery, diverting a large amount of medium to the body and tail of the pancreas and suggesting hypervascularization (Fig 6)

*Non-beta-cell tumors with the Zollinger—Ellison syndrome* Three patients were studied, one of whom has been reported previously (Boijsen 1965) At selective hepatic angiography there was a local recurrence of a highly vascular non-beta-cell tumor, the original tumor having been resected Small nodular, richly vascularized metastases were present One patient refused operation and the diagnosis of a 20 mm growth in the duodenal wall was thus not substantiated The lesion was moderately vascularized and contained only a slight accumulation of contrast medium

The third patient had severe epigastric pain and ulceration of the second part of the duodenum The upper gastrointestinal examination suggested ulcerating carcinoma of the head of the pancreas but no tumor was observed at angio-

according to BREIDAHL et coll (1955), occur in 10 to 12 % of patients One patient of the present series had two growths, one demonstrated by celiac angiography while the other became apparent only after superior mesenteric angiography

It was not possible by angiographic means to differentiate between the various types of functioning growths The same type of tumor vessels was observed in all except two small neoplasms, one insulin producing, and one ulcerogenic, in neither of which tumor vessels were observed The non functioning islet cell growths had more abundant tumor vessels and were larger than the functioning neoplasms

The long lasting accumulation of contrast medium in the tumors reported by OLSSON (1963) is a common occurrence but not always demonstrated Films of high quality should reveal a local, well circumscribed accumulation of contrast medium This is important to recognize in order to avoid a false positive diagnosis, as occurred with one of the patients in whom collateral vessels were thought to represent tumor vessels Displacement of small pancreatic arteries in small growths is another finding that should increase the safety of diagnosis

Pancreatic veins are not normally filled following injection into the splenic artery (LUNDERQUIST 1965) Pancreatic veins draining the beta cell tumors, even when small in size, were demonstrated in seven out of nine patients of our series. Accumulation of contrast medium and demonstration of pancreatic veins were also observed in endocrine tumors of non beta cell origin and in inactive neoplasms

Ulcerogenic growths were malignant in 60 % of the patients, benign in 30 % and in 10 % diffuse hyperplasia of the pancreas was present According to ZBORALSKE & AMBERG these tumors have never been observed by barium meal examinations before surgery or autopsy, but the gastrointestinal study is nevertheless so characteristic that it is the roentgenologist s responsibility to predict the diagnosis The growths are usually not large enough to be observed during exploration for gastric resection, and even careful examination of the pancreas may fail to reveal a tumor 2 cm in diameter (FONTAINE et coll 1965) ZOLLINGER & MOORE (1968) recommended that a careful examination of the pancreas be performed when there are characteristic signs of an ulcerogenic tumor, and if no tumor is found that resection of the body and tail of the pancreas should be made Preoperative angiography should therefore be carried out in these patients to depict the total vascular anatomy of the pancreas and a possible tumor Due to the small size of the tumors in the early stages of the disease, celiac and superior mesenteric angiographies should be regarded as screening procedures and should therefore, if negative, be complemented by injection into the splenic artery The subtraction technique may be helpful, as was the case in one of our patients

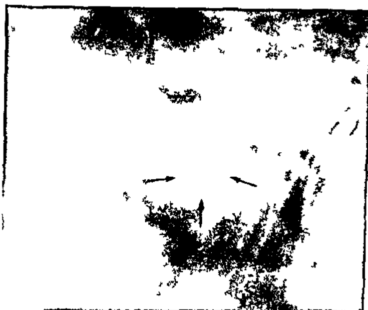


Fig 7 Benign ulcerogenic tumor of the body of the pancreas in a 69 year old man Combined celiac and superior mesenteric angiography was performed with negative results Operation revealed an 8 mm large insuloma in the body of the pancreas In retrospect identification was possible after subtraction of the angiographic studies (arrow)

SEN 1966), but as it is a somewhat more complicated procedure it should be used only in selected cases

So far insulin producing pancreatic tumors with a diameter of less than 10 mm have not been demonstrated by angiography Injection into the splenic artery will reveal the smaller tumors although it is doubtful whether a mass less than 5 mm in diameter could ever be demonstrated by this method Vascular metastases in the liver from the pancreas were however revealed by the method even when they were less than 5 mm in size (Fig 8)

One important factor in pancreatic angiography is the demonstration of the entire pancreatic arterial supply The combined injection of contrast medium into the celiac and superior mesenteric arteries is usually satisfactory in depicting the pancreatic blood supply but failed to do so in one of the present patients because of an aberrant right hepatic artery that arose directly from the aorta A thorough knowledge of the normal and usual variations of the pancreatic vascular anatomy is necessary in order to understand small changes in the course and distribution of the vessels Even if a tumor is detected by celiac angiography alone, the whole pancreatic supply should still be demonstrated, i e by superior mesenteric angiography as well This is necessary because multiple tumors may be present which,



Fig 9 Celiac stenosis and accessory spleen in an 18-year-old man The barium examination suggested a mass in the head of the pancreas but such examinations later as well as angiography confirmed that the wide ...
disclosed stenosis of the celiac ar...
contrast medium medial to the lo...
was in keeping with the mass bei... accessory spleen

one of our false positive cases in which the large amount of contrast medium was aimed for the celiac artery but was inadvertently injected into the dorsal pancreatic artery and accumulated in the body and tail of the pancreas Failure to recognize the position of the catheter may result in a false positive interpretation

From a ...

... to those of an insuloma Cystadenomas of the pancreas are also richly vascularized and may simulate an endocrine tumor although the cyst formation will often appear in the capillary phase

A small accessory spleen may be closely related to the pancreatic tail (Fig 9) Even if no tumor vessels could be detected, the contrast medium remained in the spleen for a long time The accessory spleen seems to have a more clearly demarcated border in the capillary phase Since tumor vessels may be absent in small endocrine growths, the sharper outline of the accessory spleen seems to be the only distinguishing feature Pharmacoangiography may, however, be a method of differentiating between these two conditions

Hepatic metastases were present in five patients (one beta cell carcinoma, one ulcerogenic carcinoma, and three carcinomas *without endocrine activity*), all but one having the appearance of highly vascularized nodular lesions of varying sizes The same type of metastases have been reported previously in tumors of endocrine pancreatic origin (Boijsen 1965, 1966, Rosch & Bret 1965, Ludin et coll 1966, McGavran et coll 1966, Hernandez & Helenon 1967) The angio-




Fig. 8. Malignant insuloma in a 30-year-old woman with jaundice. a) and b) Celiac angiography disclosed a richly vascularized 40 mm tumor in the head of the pancreas; small metastases were present in the liver. The tumor was resected but the hepatic metastases could not be found. c) Two months later repeat celiac angiography revealed a local 30 mm recurrence of the tumor (arrows) and small hepatic metastases. (Partial injection into the right inferior phrenic artery.)

False positive angiograms of insuloma have been reported (Rösch & Bret, Nebesar & Pollard). It appears that misinterpretation may arise from an injection of contrast medium directly into the pancreatic arteries. This occurred in

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graphic appearances seem to be characteristic and to be observed easier with angiography than with scintigraphy of the liver. In two of the present patients scintigraphy was normal despite multiple metastases having been present at angiography. Metastases of insulin-producing carcinomas may, however, when small, pass unobserved (MADSEN 1968), as also noted in a patient of the present series.

## SUMMARY

Contrast medium was injected into the splenic or hepatic arteries in fourteen patients with various types of endocrine tumors of the pancreas. Abnormal appearances were observed in all but one patient. The differential diagnosis is discussed. The method would appear to be a safe and reliable one for diagnosing neoplasms originating from the islet cells of the pancreas.

## ZUSAMMENFASSUNG

Angiographie der A. splenica oder der A. hepatica wurde in vierzehn Patienten mit verschiedenen *endokrinen Tumoren des Pankreas vorgenommen. Abnorme Befunde wurden in* allen mit Ausnahme von einem Patienten beobachtet. Die Differenzialdiagnose wird besprochen. Die Methode erscheint sicher und zuverlässlich für die Diagnose von Inselzellentumoren.

## RÉSUMÉ

Les auteurs ont injecté un moyen de contraste dans l'artère splénique ou dans les artères hépatiques de quatorze malades atteints de différents types de tumeurs endocriniennes du pancreas. Ils ont trouvé des images anormales chez tous ces malades sauf un. Ils étudient le diagnostic différentiel. Cette méthode semble sans danger et fidèle pour le diagnostic des *néoplasies provenant des cellules insulaires du pancréas.*

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FROM THE DEPARTMENTS OF NEUROLOGY (DIRECTOR E KUGELBERG) AND NEURO-RADIOLOGY (DIRECTOR T GREITZ), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

# CAROTID ANGIOGRAPHY IN CLUSTER HEADACHE

by

K EKBOM and T GREITZ

The pathogenesis of cluster headache is not completely understood Most authors have suggested that the pain is due to local dilatation of branches of the external carotid artery (HORTON 1956, 1961, FRIEDMAN & MIKROPOULOS 1958, WOLFF 1963) with release of a pain threshold lowering substance into the peri vascular tissues It is well recognized, however, that some patients may exhibit signs of a partial Horner s syndrome, either permanently or only transiently during the attacks This seems to indicate that in these patients the lesion responsible for the actual pain is localized in the internal carotid artery as well

It is a matter of interest that the headache in repeated attacks occurs strictly unilateral on the same side of the head Only occasionally does the pain alternate from side to side This clearly contrasts with migrainous headaches and suggests a different pathophysiologic basis for the attacks Hitherto no definite explana tion has been offered for this peculiar type of headache The present study was undertaken on the hypothetical basis that anatomical variations in the size of the carotid artery, e g arteriectasis, in relation to the bony structures of the skull, particularly its foramina, might be of significance in cluster headache All carotid angiographies performed in patients with this condition were therefore carefully examined and particular attention paid to the caliber of the internal carotid artery and its branches at different levels The measurements were compared

Submitted for publication 28 October 1969

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*It is* a matter of interest that the headache in repeated attacks occurs *strictly unilateral* on the same side of the head Only occasionally does the pain alternate from side to *side* *This clearly* contrasts with *migrainous headaches* and suggests a different pathophysiologic basis for the attacks *Hitherto* no definite explanation has been offered for this peculiar type of headache The present study was undertaken on the hypothetical basis that anatomical variations in the size of the carotid artery, e g arteriectasis, *in relation* to the bony structures of the skull, part ... headache All carotid ... ere therefore carefully ... f the internal carotid ... and its branches at *different* levels The measurements were compared

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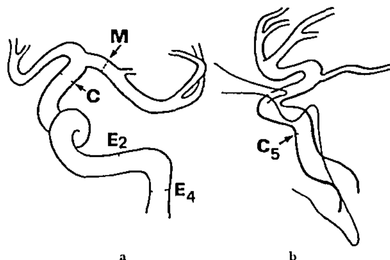



Fig 1 Diameters of the internal carotid and middle cerebral arteries determined in a p (a) and lateral (b) roentgenograms at carotid angiography

with controls having normal findings at angiography In addition, one patient was studied during an attack It appears that such investigations have not previously been carried out

*Material and Methods* The material consisted of 18 patients (13 men and 5 women) aged 25 to 62 years (mean 40 3 years) investigated during the period 1947—1969 Thirteen patients were personally interviewed by one of the authors, the histories in the remainder being obtained from the case records The clinical diagnosis of cluster headache was made mainly according to the criteria given by SCHILLER (1960), HORTON (1961) and the AD HOC COMMITTEE on 'Classification of Headache (1962) Two patients had the 'upper and sixteen the 'lower' syndrome of cluster headache (EKBOM & KUGELBERG 1968)

*Carotid angiography* This was performed by percutaneous puncture of the internal or common carotid artery Sodium- and methyldiatrizoate (Urografin) was used as contrast medium in about two-thirds of the patients with cluster headache as well as in the controls In the remainder, iodopyracet (Umbradil) was mostly used In nine patients, carotid angiography was performed on the right side, in eight on the left, and in one patient bilaterally Seven patients were investigated as a routine procedure prior to resection of the greater superficial petrosal nerve (GARDNER et coll 1947), while the remainder of the patients underwent angiography for diagnostic purposes early in the course of disease One patient was studied during an attack of headache, which presumably was elicited by the injection of the contrast medium

**Table 1**

*Prediction equations for mean values of diameters in millimeters of internal carotid artery within the carotid canal ($E_2$ and $E_4$) as influenced by sex and external biparietal diameter (W expressed in centimeters) — These equations are determined from a 'normal' material of 60 males and 62 females*

| Measurement | Male | Female |
|---|---|---|
| $E_2$ A p projection | 3.093 + 0.2698 W | 2.370 + 0.2698 W |
| $E_2$ Half axial projection | 3.610 + 0.2698 W | 2.887 + 0.2698 W |
| $E_4$ A p projection | 5.101 + 0.0874 W | 4.789 + 0.0874 W |
| $E_4$ Half axial projection | 5.518 + 0.0874 W | 5.205 + 0.0874 W |

The influence of sex on measurement $E_2$ is significant at the 0.1 % level and the influence of projection is significant at the 1 % level The influence of skull width is significant at the 5 % level With regard to $E_4$ the corresponding significance levels are 5 %, 1 % and not significant

*Angiographic measurements* Measurements of the internal carotid and middle cerebral arteries were performed (Fig 1) 'Normal' values for the extradural part of the internal carotid artery ($C_5$), for the intradural part (C) and for the middle cerebral artery (M) were obtained according to GABRIELSEN & GREITZ (1970) The normal material of these authors consisted of 156 strictly selected angiographies from 72 males and 84 females aged 13 to 69 years (mean 33 years) Most of the patients had a clinical diagnosis of epilepsy (For further details, see GABRIELSEN & GREITZ ) The standard error of measurement related to a single determination was estimated to be less than 0 15 mm for these measurements Because anatomical variations of the internal carotid artery in relation to the bony structure of the skull might possibly be of significance in the pathogenesis of cluster headache, two additional measurements were obtained (Table 1), one at the midpoint of the horizontal part of the carotid canal ($E_2$) and one measurement close to its external aperture ($E_4$) These measurements were also made in 122 of the 156 patients whose angiographies had been used as controls in the above mentioned study (GABRIELSEN & GREITZ) The excluded 34 angiographies had filling insufficient for accurate measurements due to the use of a non serial angiographic technique

## Results

*1 General angiographic findings* Four of the eighteen patients had generalized ectasia of all cerebral arteries They were all males, in addition, two females had questionable ectatic changes In the remaining patients, the findings at carotid angiography were essentially within normal limits Two patients with ectasia

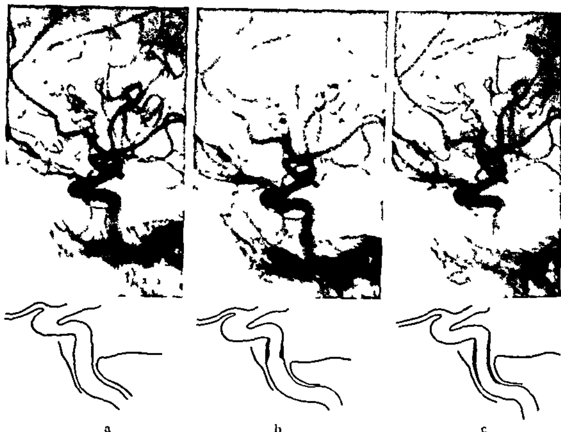



Fig. 2. Appearances of the carotid siphon before and during an attack of cluster headache before the onset of pain (a), a few minutes after the beginning of the attack (b), and shortly before its termination (c). The thick contours in the explanatory sketches indicate constricted areas.

had additional angiographic studies: one was examined with vertebral angiography and the other with aortocervical angiography. These examinations also revealed ectatic cerebral vessels. One female patient without arteriectasis when first examined was found by aortocervical angiography, performed 19 years later at the age of 52, to have developed generalized ectasia. She had not had any period of headaches for the previous 17 years.

2. *Angiography during an attack of cluster headache.* One patient was examined before and during an attack.

This patient was a 42-year-old man, who was admitted to hospital with recurrent attacks of severe headache, occurring mostly during the night and lasting for 20 to 30 minutes at a time. The pain was always localized to the left eye and referred to the teeth of the upper jaw. Associated signs during the attacks were conjunctival injection, lacrimation, rhinorrhoea, sweating and a homolateral partial Horner's syndrome (miosis and ptosis).

**Table 2**

*Mean values ± S D for various diameters of the cerebral arteries expressed in millimeters*

| | Cluster headache observed values | Normal cases observed values | Normal cases adjusted values | Difference between values in cluster headache and adjusted normal values |
|---|---|---|---|---|
| C | 4.87 ± 0.60 (n = 17) | 4.57 ± 0.46 (n = 156) | 4.78 | +0.09 |
| M | 4.18 ± 0.50 (n = 17) | 3.82 ± 0.43 (n = 156) | 4.16 | +0.02 |
| $C_s$ | 6.60 ± 0.77 (n = 18) | 5.80 ± 0.76 (n = 156) | 6.33 | +0.27 |
| $E_2$ | 7.30 ± 1.12 (n = 17) | 7.19 ± 1.02 (n = 122) | 7.76 | −0.46 |
| $E_4$ | 6.74 ± 0.82 (n = 17) | 6.48 ± 0.73 (n = 122) | 6.71 | +0.03 |
| C + M + $C_s$ | 15.65 ± 1.44 (n = 17) | 14.19 ± 1.31 | 15.26 | +0.39 |

Carotid angiography was performed by puncture of the left internal carotid artery Rapid serial angiography was used with two films a second during the arterial phase The appearances of the carotid artery during the first series of films before the onset of headache are demonstrated in Fig 2a Fifteen minutes after the injection of the contrast medium (Urografin 60 %) the patient developed severe headache, which was identical to his spontaneous attacks A second injection of contrast medium was then made, and films were taken in the same projection Localized narrowing of the extradural part of the internal carotid artery (Fig 2b) was observed distal to its exit from the carotid canal (corresponding to the area in which measurement $C_s$ was taken) The ophthalmic artery was markedly dilated About 15 to 20 minutes later, the patient experienced slight pain in the left eye but not in the upper jaw A third injection was then made and another film was obtained (Fig 2c) It was observed that the narrowing had spread in a proximal direction as far as the upper part of the carotid canal

3 *Angiographic measurements* The results of the measurements of the various diameters of the cerebral arteries are given in Table 2 The observed mean values in patients with cluster headache were all greater than in the 'normal material The observed normal values were adjusted for those variables that had turned

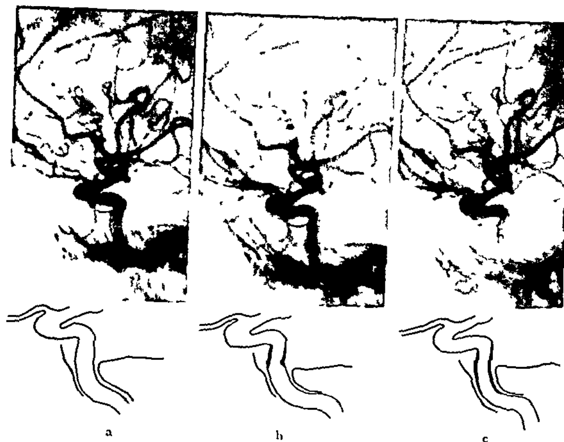



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The literature records a few isolated instances of cluster headache in which the anatomy of the cerebral arteries was unusual Thus, HORTON (1941) described a 31 year old male who was operated upon because of intractable pain The middle meningeal artery, explored through a subtemporal craniotomy, was found to be large and tortuous and to have a particularly large posterior branch SAFER (1962) reported the case of a 26 year-old man with severe cluster headache, who underwent ligation of the common carotid artery At operation, the carotid bifurcation was found to be normal but the internal carotid artery was almost a direct continuation of the common carotid artery and was increased in size The external carotid artery, on the other hand, was much smaller than usual Following the operation the headache disappeared but the exact length of the observation period was not given in SAFER's paper In six patients on the other hand, carotid angiography was stated to be normal NIEMAN & HURWITZ)

Our results showed that some patients with cluster headache have generalized ectasia of cerebral vessels The mean values of all measurements of arterial size were greater than in the normal material (GABRIELSEN & GREITZ) but this tendency disappeared after adjustments for the fact that most patients with cluster headache were males and (independent of sex) had fairly wide skulls The latter observation is of particular interest as it has been suggested that patients with cluster headache have unusually broad skulls (GRAHAM 1969) This matter will be further investigated in a future work

It is well recognized that the tone of cerebral arteries are chiefly regulated by the arterial $_pCO$ and blood pressure (cf INGVAR & LASSEN 1965) Vasoconstriction has been observed at cerebral angiography during hypocapnia (HUBER & HANDA 1967) Admittedly, no determinations of $A_pCO_2$ or blood pressure were made in our patients However, there seems to be no obvious reason to presume that any systematic differences as regards these parameters have been present between the normal material and the patients with cluster headache It would not appear either that the results were biased by differences in the vascular activity of the different contrast media as these were used in largely the same proportions in both materials

The narrowing of the extradural parasellar part of the internal carotid artery seen during the height of the headache attack in one of our patients could have been due to either spastic contraction or oedema of the wall of the vessel The fact that it appeared only a few minutes after the onset of symptoms may speak slightly in favour of spastic contraction

However it is well recognized that a certain latency period precedes the induced attack of headache (HORTON 1961, EKBOM 1968) and during this period oedema may develop The narrowing seen within the bony canal cannot

out to be of importance in each exploration. Measurements M, C and $C_3$ were adjusted to correspond to patients with epilepsy, examined with rapid serial angiography and having normal findings at encephalography. Normal values for $E_2$ are mean values for all patients measured and therefore include those with migraine and other types of headache as well as those with epilepsy. The normal values were further adjusted with respect to the following variables: sex and skull width for C, M and $C_5$; sex, skull width and projection for $E_2$ and $E_1$. This amounts to calculating the arterial sizes that would be met in a normal material having a composition comparable to the present material with cluster headache. In consequence, differences between values expected by this adjustment and average arterial sizes observed in the cluster headache series cannot reasonably be ascribed to these variables. After the adjustment, differences exceeding 0.15 mm were observed only for two individual measurements ($C_5$ and $E_2$) but these differences were not significant ($P > 0.05$).

## Discussion

There is reason to assume clinically that cluster headache attacks are preceded by or associated with a change of the autonomic nervous control of the tone of certain cranial arteries. Presumably, a limited area of the vascular tree is involved. The attacks are characterized by signs and symptoms indicating a local increase of parasympathetic activity (GARDNER et coll. 1947). In this connection the presence of signs of a partial Horner's syndrome is of interest. In contradistinction to a complete Horner's syndrome, there is no anhidrosis over the face during cluster headache attacks. On the contrary, ipsilateral hyperhidrosis of the forehead is not uncommon and indicates stimulation of sympathetic nerve fibres travelling along the external carotid artery to supply the sweat glands. Observations made by KUNKLE & ANDERSON (1960) and NIEMAN & HURWITZ (1961) suggest that these minor eye signs are caused by oculosympathetic paresis rather than parasympathetic stimulation. This partial Horner's syndrome might be due to repeated dilatation and oedema of the internal carotid artery resulting in damage to the sympathetic nerves that surround the vessel.

A detailed analysis of the size of relevant segments of the internal carotid artery in relation to corresponding measurements in a control group was therefore considered to be of interest. It was felt that measurements at different levels in the carotid canal as well as of the intracranial extradural portion of the artery would be of particular significance. Normally, these portions of the carotid have an external elastic lamina, which apparently is not present in its intradural portion or in any of the other cerebral vessels (RATINOV 1964).

## ZUSAMMENFASSUNG

Karotisangiographie wurde an 18 Patienten mit Horton'schem Kopfschmerzsyndrom ausgeführt, von denen vier eine ausgeprägte Erweiterung und zwei mögliche Erweiterung der Arterien hatten Während der akuten Attacke konnte eine lokalisierte Verengung des extraduralen Abschnittes der A carotis interna deutlich festgestellt werden, im Endstadium der Attacke erstreckte sich die Verengung bis zum oberen Abschnitt des Karotiskanals Diese Veränderungen wurden wahrscheinlich durch Kontraktion der Arterienwand und vom Ödem hervorgerufen

## RÉSUMÉ

Les auteurs étudient chez 18 malades les résultats de l'angiographie carotidienne dans le cluster headache' Quatre de ces malades avaient une ectasie artérielle nette et deux avaient une ectasie douteuse Au cours d une crise il y avait un rétrécissement localisé net de la partie extra durale de la carotide interne, au stade final de la crise le rétrécissement s'était étendu jusqu à la partie supérieure du canal carotidien Il est possible que ces modifications soient dues à la constriction et à l'oedeme de la paroi artérielle

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be due to spastic contraction only, as this would bring about a vacuum between the vessel wall and the cortex of the bone. Vacuum phenomena are known in connection with extension of joints and degenerated discs and are clearly seen at roentgen examination. Hence, the only possible explanation for the increase of soft tissues within or outside the wall of the vessel is an increase in fluid, i.e. oedema. The changes observed in this portion of the artery seem to develop more slowly than in the parasellar part, which is not completely surrounded by bone. The narrowing of the internal carotid artery remained or even increased after the period of maximal pain and may possibly be the initiating factor that relieved the headache. In this connection, radiologic observations made in ophthalmoplegic migraine are of interest. WALSH & O'DOHERTY (1960), in two cases of ophthalmoplegic migraine, demonstrated narrowing of the internal carotid artery in the cavernous sinus. This was interpreted as evidence of an oedematous swollen vessel, these changes being precipitated by the migrainous attack. BICKERSTAFF (1964) performed carotid angiographies in ten cases of ophthalmoplegic migraine and observed in one of them, 48 hours after the onset of symptoms, a distinct constriction of the vessel in and below the region of the cavernous sinus. After complete recovery angiography was repeated and found to be normal. Similar changes, although to a lesser degree, were recorded in four other cases. This seems to indicate that oedema or constriction of the arterial wall, might have contributed to the peripheral nerve palsies in these cases.

Several carotid arteriographies have however been performed in patients during ophthalmoplegic migrainous attacks without any demonstrable abnormalities (FRIEDMAN et coll. 1962, PEARCE 1968).

## Acknowledgements

*This investigation was supported by a grant (to T. G.) from the Medical Research Council of the Swedish Life Offices. We are grateful to Prof. Lars Leksell and Dr. Torsten Bingley for permission to study the patients from the Department of Neurosurgery.*

## SUMMARY

The findings at carotid angiography were analyzed in 18 patients with cluster headache of whom four patients had definite and two questionable arteriectasis. Localized narrowing of the extradural part of the internal carotid artery was observed during an attack in the final stage of which the narrowing had spread to the upper part of the carotid canal. These changes are possibly due to constriction and oedema of the arterial wall.

## ZUSAMMENFASSUNG

Karotisangiographie wurde an 18 Patienten mit Horton'schem Kopfschmerzsyndrom ausgeführt, von denen vier eine ausgeprägte Erweiterung und zwei mögliche Erweiterung der Arterien hatten. Während der akuten Attacke konnte eine lokalisierte Verengung des extraduralen Abschnittes der A. carotis interna deutlich festgestellt werden, im Endstadium der Attacke erstreckte sich die Verengung bis zum oberen Abschnitt des Karotiskanals. Diese Veränderungen wurden wahrscheinlich durch Kontraktion der Arterienwand und vom Ödem hervorgerufen.

## RÉSUMÉ

Les auteurs étudient chez 18 malades les résultats de l'angiographie carotidienne dans le cluster headache. Quatre de ces malades avaient une ectasie artérielle nette et deux avaient une ectasie douteuse. Au cours d'une crise il y avait un rétrécissement localisé net de la partie extra durale de la carotide interne; au stade final de la crise le rétrécissement s'était étendu jusqu'à la partie supérieure du canal carotidien. Il est possible que ces modifications soient dues à la constriction et à l'oedème de la paroi artérielle.

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# SIALOGRAPHY OF THE SUBLINGUAL GLAND

## A modified technique enabling subtraction

by

B LILIEQUIST and U WELANDER

Sialography is a roentgenologic method mainly applied in the examination of the parotid and submandibular glands Roentgen examination of the sublingual gland has not been used to the same extent, probably because of the unfavourable anatomic relations of the gland with its many short excretory ducts often opening separately along the sublingual fold GARUSI (1964) maintained that it is seldom possible to achieve contrast filling of the duct system of the sublingual gland, and that on the rare occasions when this is obtained the result is usually unsatisfactory He had however succeeded where Bartholin s duct or the ducts of Rivinus from the larger or smaller portion of the sublingual gland opened into the excretory duct of the submandibular gland This was also pointed out by HETZAR in 1942 and recently by SCHULZ (1969), who also succeeded with selective catheterisation in 12 patients

The sublingual gland is a salivary organ, measuring 3 cm in length and 1 cm in width and depth, situated anteriorly on the floor of the mouth in immediate relation to the mylo-hyoid muscle and the inner surface of the mandible, it produces a long ridge, the sublingual fold on the floor of the mouth The posterior

Submitted for publication 3 July 1969



Fig 1 a) The duct system of a sublingual gland filled via Wharton's duct b) An excretory duct of a sublingual gland filled by selective catheterisation

part of the gland is sometimes in contact with the anterior surface of the submandibular gland

The excretory ducts of the sublingual gland may vary considerably in number, as many as 48 ducts, each one opening separately on the sublingual fold, have been recorded Usually, however, there is one large common duct, the duct of *Bartholin, running from the larger part of the gland, and one or several lesser* passages, the ducts of Rivinus, leading from a smaller part of the gland Bartholin's duct is a long passage terminating either in Wharton's duct immediately behind its orifice, or in a separate opening immediately beside the orifice The smaller excretory ducts may also open into the submandibular duct, and when this occurs their openings lie in its proximal segment

These anatomic relations make it difficult to work out a roentgenologic method for examination of the sublingual gland Where the gland has many separate excretory ducts, an examination can be carried out only when one or other of these can be catheterized When one or several passages open into the submandibular duct the situation is different On the few occasions in which the sublingual gland has filled incidentally in connection with sialography of the submandibular gland the same type of pathologic changes have been observed in this gland as in the other salivary glands Improvement in the technique of sialography in such a way that the sublingual gland could also be investigated when the anatomic relations permit would obviously be of value

Polythene catheters, introduced into Wharton's duct are used nowadays for

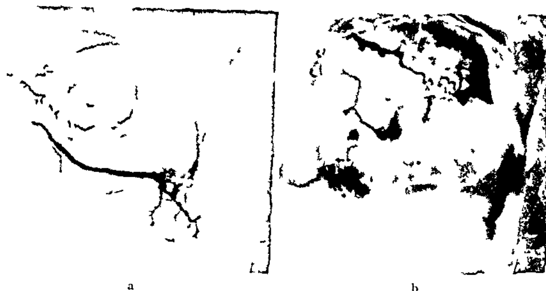



Fig. a) A sublingual gland filled selectively via Wharton's duct. b) The duct system of a submandibular gland filled after the catheter had been passed farther into the excretory duct of the gland.

sialography of the submandibular gland. The duct is narrowest at its orifice and for the rest of its length its calibre is usually greater. Without preliminary catheterisation with metal cannulae a large catheter cannot be inserted unless its tip is extended. When the sublingual gland is to be included in the sialographic examination the catheter should not be passed for any distance into Wharton's duct but should rather be placed so that the increasing calibre of the catheter occludes the orifice. If the extended tip is short, the contrast medium can be injected into Wharton's duct immediately behind the orifice; this is the only way by which the excretory ducts opening into Wharton's duct from the sublingual gland can be filled.

The sublingual gland is fairly small and its position is such that it overlies the mandible in lateral roentgenograms. This is another reason why the gland is difficult to identify at sialographic examinations. The present authors have demonstrated in another connection (LILJEQUIST & WELANDER 1969) that a simple modification of the sialographic procedure enables the subtraction technique to be applied in sialography of the parotid gland. Narrow passages, even if depicted in enclosing bone structures, may thus be identified. The subtraction technique is therefore of great value in the study of the sublingual gland. A film changer permitting the exposure of several roentgenograms without any movement of the patient during the examination has proved valuable in this connection.

The authors have used this method in bilateral sialography of the submandibular and sublingual glands in 10 patients. The duct system of the sublingual



a b

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Fig 4 An overfilled sublingual gland after selective injection of contrast medium



Fig 5 Bartholin's duct a long excretory duct running parallel to and of the same width as Wharton's duct

amounts are required for the examination of the duct system of the sublingual gland Great care should be exercised during the injection so as to avoid the risk of overfilling (Fig 4)

Bartholin's duct is a relatively long passage which, for part of its course, runs alongside Wharton's duct (Fig 5) It is sometimes of large calibre, especially when it serves as the main excretory duct for the larger part of the sublingual gland Parenchymal filling was obtained in all patients and this was of assistance in the assessment of the size and shape of the gland Changes of the same type as those seen in sialectasia of the parotid and submandibular glands were evident in one of the patients (Fig 3a)

The examinations of the sublingual gland so far performed are still too few for definite conclusions to be reached regarding the value of the method, the frequency of pathologic changes, and their relation to changes in other salivary glands Similarly, no conclusion can yet be drawn as to how often the duct system of the sublingual gland can be demonstrated with this method

## SUMMARY

The sublingual gland and its ducts have been successfully demonstrated in a small number of patients by means of a simple modification of the sialographic procedure The factors concerned in obtaining filling of the gland are discussed

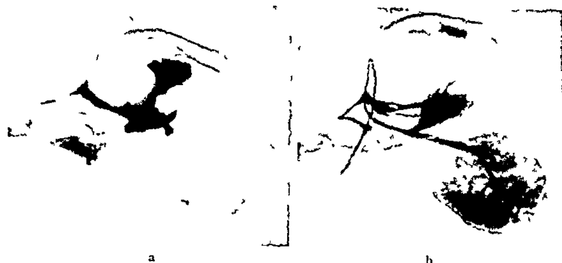



Fig 3 a) Selective filling of Bartholin's duct Areas of sialectasia in the sublingual gland b) The ducts of Rivinus and the excretory duct of the submandibular gland filled at a later stage of the examination

gland could be filled through the submandibular duct (Fig 1a) in 5 of the patients, in one the duct system of the sublingual gland alone was outlined through selective catheterisation of its excretory duct (Fig 1b) In one of the 6 patients an anterior and a posterior part of the sublingual gland was filled through two different excretory ducts Thus, in 5 out 20 examinations, the duct system of the sublingual gland was outlined through Wharton's duct and in 2 patients selective catheterisation could be performed Furthermore, in 2 of the patients selective filling of the sublingual gland alone was achieved during the first stage of the examination (Fig 2a) Afterwards, when the catheter was introduced a little further and more contrast medium injected, the duct system of the submandibular gland was also demonstrated (Fig 2b) In one of these patients first Bartholin's duct and then Rivinus ducts were demonstrated (Fig 3, a and b)

Thus if the extended part of the catheter tip is placed immediately inside the orifice in the first stage of the examination, the duct system of the sublingual gland may usually be demonstrated In the second stage, the catheter is pushed further into Wharton's duct in order to demonstrate the duct system of the submandibular gland, if this has not already been achieved during the first stage Selective filling of the sublingual gland may also be obtained by passing the catheter tip into passages that open beside the main excretory duct of the submandibular gland

The authors employ Urografin 60 % as contrast medium, only very small

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# TRANSCAVAL INJECTION OF THE PORTAL VEIN

## A preliminary report on a new technique

by

M. HAVERLING, C.-O. OVENFORS and S. DAHLGREN

Progress in the field of surgery during recent years has rendered possible operative treatment of lesions of the liver, such as primary tumours, solitary metastases and echinococcus cysts. Pre-operative localization of the intraparenchymatous lesion and of the hepatic vessels by angiography has thus increased in significance. Methods for demonstrating the portal veins are described in the literature, i.e. coeliacography (ÖDMAN 1958), splenoportophlebography (ABEATICI & CAMPI 1951, ARNER & FERNSTRÖM 1965, BERGSTRAND & EKMAN 1957, BOULVIN et coll. 1952, LEGER et coll. 1951) and injection of the portal vein, via mesenteric veins (ABEATICI & CAMPI 1951, MOORE & BRIDENBAUGH 1950) or the umbilical veins (BOULVIN et coll. 1951, KESSLER & ZIMMON 1966). Selective examination of the hepatic veins with contrast medium may also be performed (NORHAGEN 1963). As these examinations provide insufficient demonstration of the vessels and may be technically difficult to perform, the authors have attempted to devise a simple yet effective procedure for better exploration of the hepatic venous system. HAVERLING & OVENFORS (1968) carried out translumbar puncture of the portal vein in pigs and in a few cases in man, the catheterization of the vessel in pigs

Submitted for publication 25 July 1969

## ZUSAMMENFASSUNG

Die Sublingualdruse und ihre Gange konnten in einer kleinen Serie von Patienten mittels einer einfachen Modifizierung der Sialographie-Technik gut dargestellt werden Die Faktoren, die zur Fullung dieser Druse fuhren, werden diskutiert

## RÉSUMÉ

La glande sublinguale et ses canaux ont été bien mis en evidence chez un petit nombre de sujets par une simple modification de la technique sialographique Les auteurs examinent les facteurs de l opacification de cette glande

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of Nembutal (Abbott) via a plastic cannula inserted in an ear vein (HAVERLING 1966) A red teflon catheter with only one hole at the tip was introduced via the right femoral vein into the inferior vena cava In the first two pigs a mesenteric vein was exposed and catheterized with a polythene catheter PE 160 Contrast medium was then injected into the portal vein via this catheter at the same time as contrast medium was injected into the vena cava

The animals were placed in the supine position for puncture of the portal vein The transseptal puncture instrument was introduced into the teflon catheter previously placed in the vena cava The tip of the instrument was pushed 2 to 3 mm outside the extremity of the catheter in the inferior vena cava and directed ventrally at the level of the lowest rib Under fluoroscopic control, the instrument was directed through the anterior wall of the inferior vena cava and guided ventrally about 4 cm further, and about as many centimetres cranially The catheter was passed over the distal part of the instrument again, the instrument was withdrawn and the catheter left in place The catheter was then slowly pulled down during continuous aspiration until blood was seen to flow The location of the catheter tip was checked by the injection of a small quantity of Urografin 76 % One to 8 punctures were made during the various experiments before the catheter could be placed in a suitable position, and in two of the experiments the location of the catheter was adjusted with the aid of a guide wire temporarily introduced into the catheter and the portal vein (SELDINGER PE 160) On one pig two puncture attempts were made with the animal in the lateral position The portal vein was punctured at the third and final attempt with the animal in the supine position

The angiographic examinations were made with the animals in lateral and supine positions with a vertical beam direction The films were exposed in an AOT Elema film changer for cut film with 2 exposures per second for 7 seconds The contrast medium (Urografin 60 %, 1 5 ml per kg body weight), was injected for each angiography The injection rate was 12 ml/sec in the first 5 experiments and 14 5 ml/sec in the remainder All pigs were in good condition after the experiments Pig No 2 was sacrificed on the day after the experiment an [illegible] ments an [illegible] vena ca [illegible] portal vein was inspected and four pieces each about 1 × 2 × 3 cm in size, were taken from different parts of the liver for microscopy

## Results

It was invariably possible to puncture and catheterize the portal vein, although several attempts were usually necessary Thus, while one puncture resulted in an




Fig 1 a) Simultaneous injection of contrast medium into the inferior vena cava and the portal vein after transcaval portal catheterization The vena cava (arrow) is almost directly dorsal to the portal vein b) Simultaneous contrast injection into the vena cava and portal vein Note the proximity of the vessels in the sagittal plane

was made by the SEIDINGER technique (1953) The films obtained demonstrate the peripheral branches of the portal vein so that the diagnosis of lesions as small as 0 5 cm in diameter is probably possible

Translumbar puncture has certain technical disadvantages A fairly large part of the portal vein lies anterior to the spine and may be difficult to puncture Both the anterior and posterior walls of the inferior vena cava must be punctured It was noted in translumbar portography (HAVELING & OVENFORS) that the inferior vena cava is situated almost directly dorsal to the portal vein in front of the third rib, as counted from below (the number of ribs in the pig is variable), and about 2 cm in a cranial direction (Fig 1) The drawbacks of the translumbar approach would be avoided if the portal vein could be catheterized from the inferior vena cava A technique has been developed whereby catheterization can be performed transcavally with an instrument constructed for transseptal puncture of the left atrium (BEVEGÅRD et coll 1961)

*Material and Methods* The experiments were performed in 11 pigs weighing between 35 and 50 kg The animals were anesthetized by intravenous injections

inferior vena cava and the portal vein and in carrying out the punctures and catheterizations If the puncture was unsuccessful at the first attempt, it was made about 1 cm cephalad in subsequent attempts, and at the same time the instrument was directed slightly to the right The puncture sites in the inferior vena cava could be easily determined by reference to the spine and ribs on fluoroscopy

On angiography of pig No 6 in the supine position, part of the contrast ... ecoil To avoid ... the catheter for ... pushed over a guide wire PE 205

Postmortem examinations in this small series indicated that there are probably no major risks involved with procedure of puncturing and catheterizing the portal vein No changes were observed in the liver at microscopy after repeated injections of Urografin 60 % in association with the examinations It was thus possible to examine the portal veins of the animals with several projections and repeated injections of contrast medium

## Acknowledgement

This investigation was supported by the James Picker Foundation on recommendation of the Committee on Radiology of the National Research Council

## SUMMARY

A new technique for direct puncture of the portal vein via the inferior vena cava, with the aid of an instrument designed for transseptal cardiac puncture is described Satisfactory demonstration of the portal vein and its branches was obtained at subsequent angiography No significant injuries attributable to the procedure could be established on macroscopic or microscopic examination of the liver in the experimental animals

## ZUSAMMENFASSUNG

Eine neue Technik fur die direkte Punktion der Portalvene via die Vena cava inferior, mit Hilfe von einem Instrument fur transseptale Herzpunktion wird beschrieben Angiographie mittels dieser Methode ermoglicht gute Darstellung der Portalvene und ihrer Äste Makroskopische und mikroskopische Untersuchung der Leber in Versuchstieren zeigte keine bedeutende Verletzungen die der Methode zuzuschreiben sind

## RÉSUMÉ

Description d une nouvelle technique de ponction directe de la veine porte par la veine cave inferieure au moyen d un instrument conçu pour la ponction cardiaque transseptale L angiographie faite par cette ponction donne des images satisfaisants de la veine porte et de ses branches L examen macroscopique ou microscopique du foie des animaux d experience n a pas montre de lesions importantes imputables à cette technique



Fig. 2. Phlebogram 2.5 sec (a) and 5 sec (b) after commencement of injection.

immediately suitable position of the catheter in one pig, two to five attempts at puncture were necessary in 8 pigs and eight attempts in 2 pigs. Demonstration of the portal veins was obtained in all the examinations (see Fig. 2 a and b). An extravascular injection of the contrast medium occurred in pig No. 6 examined in the supine position.

No change of any kind could be established on microscopy of the livers. Postmortem inspection of the puncture zone between the inferior vena cava and the portal vein usually revealed nothing abnormal. Small red spots in the intima were observed on the anterior wall of the inferior vena cava and both the anterior and posterior walls of the portal vein in pig No. 2; these were probably caused by small intimal bleedings following the punctures.

## Discussion

With the exception of pigs Nos. 1 and 2, the transcaval punctures of the portal vein were performed without previous localization of the portal vein by mesenteric phlebography. In pig No. 1, the first 2 punctures were made with the animal in the lateral position. The third and fourth punctures, which were both successful, were made with the animal in the supine position. It appeared easier to guide the instrument with the animals in the supine position and consequently subsequent punctures were made in this manner. Fluoroscopy in two planes naturally would have been of value, but the prerequisites for this did not exist during the experiments. With the aid of the experience gained from previous experiments, there was no difficulty to establish the anatomic relationships of the

# RETINAL AND CEREBRAL FAT EMBOLI FOLLOWING LYMPHOGRAPHY WITH OILY CONTRAST MEDIA

by

K F RASMUSSEN

The complications of lymphography with oily contrast media are usually mild and transitory, e g general malaise, nausea, headache, elevated temperature, and in some instances allergic cutaneous reactions (DOLAN 1966). At the first International Symposium on Lymphology, July 1966, in Zurich (PROGRESS IN LYMPHOLOGY) serious sequelae were reported in 198 out of 16 501 lymphographies (18 with a fatal outcome) These consisted of pulmonary infarcts (96 cases), pneumonia (27 cases), pulmonary oedema (10 cases), cerebral affections (8 cases), and other serious conditions (e g anuria, hyper- or hypotensive crisis, acute cardiac failure, and venous and arterial thrombosis) (57 cases)

The cerebral complications manifest themselves in various neurologic signs, such as changes in consciousness, confusion, excitement followed by stupor and possibly coma — depending upon the severity and localization of the cerebral anoxaemia (EMSON 1961)

One case of cerebral complications and retinal fat emboli has occurred in some 750 lymphographies of the present material

## Case report

Woman aged 35 with stage IV Hodgkin's disease, who had hepatomegaly, a mediastinal mass right pleural effusion and bilateral pulmonary infiltration only slight enlargement of

Submitted for publication 30 July 1969

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# RETINAL AND CEREBRAL FAT EMBOLI FOLLOWING LYMPHOGRAPHY WITH OILY CONTRAST MEDIA

by

K. E. RASMUSSEN

The complications of lymphography with oily contrast media are usually mild and transitory, e.g. general malaise, nausea, headache, elevated temperature, and in some instances allergic cutaneous reactions (DOLAN 1966). At the first International Symposium on Lymphology, July 1966, in Zurich (PROGRESS IN LYMPHOLOGY) serious sequelae were reported in 198 out of 16 501 lymphographies (18 with a fatal outcome). These consisted of pulmonary infarcts (96 cases), pneumonia (27 cases), pulmonary oedema (10 cases), cerebral affections (8 cases), and other serious conditions (e.g. anuria, hyper- or hypotensive crisis, acute cardiac failure, and venous and arterial thrombosis) (57 cases).

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One case of cerebral complications and retinal fat emboli has occurred in some 750 lymphographies of the present material.

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Submitted for publication 30 July 1969.



Retinal photo (Ectachrome X) of the right and left eyes respectively. Effusions of the oil contrast medium and a few small haemorrhages following lymphography.

the lymph nodes could be seen. The patient however felt well and had no neurologic signs. Lymphography of the retroperitoneal lymph nodes was performed, 0.8 ml patent blue violet (without any added local anaesthetic) being injected into the first intermetacarpal spaces of both feet. By half an hour the lymphatic vessels on the dorsa of the feet became distinct and under local anaesthesia (lidocaine with adrenalin) a lymphatic on each side was injected with 8 ml oily contrast medium (Lipiodol ultrafluide) during 2 hours. There were *no symptoms in direct connections with the lymphography* but the patient *gradually* became drowsy and about 5 hours after the lymphography appeared to be unable to see.

Ophthalmologic examination the same afternoon revealed doubtful perception of light but normal pupillary reactions. Ophthalmoscopy indicated bilateral mild retinal oedema, several *small shiny whitish yellow spots* which *were assumed to represent* contrast medium in the end arteries while at a few sites in or around the vessels small grey ill defined effusions and a few small round haemorrhages were evident (see figures). The disks were normal. The patient could answer only simple questions, exhibited right left confusion and acalculia. Mild diffuse weakness of the upper limbs and a trace of reflex preponderance with a positive Babinski sign of the right leg were present. During the next three days the condition was practically unchanged, the patient remained drowsy although an ophthalmologic examination indicated that the ischaemic retinal oedema was regressing. During the subsequent week she slowly picked up and on the tenth day after the lymphography the vision was again practically normal although ophthalmoscopy still revealed *droplets of* the contrast medium in the vessels and ill defined greyish effusions. Ophthalmologic examination three weeks later: Vision in both eyes 0.67. Perimetry 6/2 000 white + red normal. The droplets of contrast medium had now disappeared but there were still greyish *effusions. Entirely normal* appearances *did not* return until six weeks later at which time the neurologic conditions were also completely normal. The patient was discharged without symptoms.

## Discussion

In the cases reported in the literature a time relation between the lymphography and the onset of the complications has existed although the latter have not always appeared in immediate connection with the examination being delayed for hours up to a few days It may be assumed therefore that the sequelae are not always due to embolization or allergy to the contrast medium, but that in some instances the reaction is of a chemical nature and caused by fatty acids split off from the medium This latter assumption would explain the cerebral complications, although fat emboli might also reach the brain by way of Batson s venous plexuses or through a right left shunt in the heart (KOEHLER et coll 1964, PROGRESS IN LYMPHOLOGY 1966)

The incidence of complications appears to be related to the amount of contrast medium injected According to DOLAN (1966), complications occurred in 13 % of cases in which 18 ml were given, in 24 % of those in which 18 to 20 ml were used, and in 48 % when more than 20 ml contrast medium had been administered The most common complications were fever, nausea, vomiting, and pain at the site of injection

The fat emboli syndrome is relatively common following fractures

FRITZ & HOGAN (1948) found the retinal capillaries to be filled with fat and there were fatty infiltrations of the surrounding stroma in patients who had died of cerebral fat emboli

The diameter of a fat embolus may range from 6 to 40 $\mu$ with the majority from 12 to 15 $\mu$ accordingly, they never occur in large vessel (RASK 1968) The small petechial haemorrhages that are generally present are due to obstruction and consequent disruption of the capillaries (NEWMAN 1948)

The blindness in the present case must be assumed to have been of a cortical nature (KINMOTH et coll 1955), with due regard to the retained pupillary reactions the fact that the ophthalmoscopic findings could not explain the visual impairment and that the patient had definite cerebral symptoms

The Lipiodol ultrafluide contrast medium may in this case conceivably have passed to the brain not only through Batson s plexuses and the pulmonary circulation but also through a bypass in the pulmonary tumour tissue

## SUMMARY

A case of fat emboli in the retina and brain following lymphography is reported The complications of lymphography and the phenomenon of retinal fat emboli are discussed

## ZUSAMMENFASSUNG

Nach Lymphographie ereignete sich in einem Fall eine Fettembolie des Gehirnes und der Retina Die Komplikation der Lymphographie und das Erscheinen einer Fettembolie der Retina werden kritisch besprochen

## RÉSUMÉ

Presentation d un cas d embolies graisseuses dans la retine et dans le cerveau apres une lymphographie L auteur examine les complications de la lymphographie et le phenomene des embolies graisseuses retiniennes

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# FIBROMUSCULAR HYPERPLASIA IN CHILDREN

by

POUL F. ANDERSEN

Since the publication by LEADBETTER & BURKLAND (1938) of the first case of fibromuscular hyperplasia of the renal artery of a pelvic kidney in a 5 year old hypertensive boy, reports on this disease in children have been exceedingly rare. The disease was disregarded for more than 20 years until the report by WYLIE & WELLINGTON (1960) again suggested a causal relation between renal hypertension and fibromuscular hyperplasia. The extensive use of nephro-angiography in the last decade has revealed a number of cases, mainly in young and middle-aged Californian women, and at the same time disclosed the occurrence of the disease in extrarenal vascular areas (WYLIE, BINKLEY & PALUBINSKAS 1966). The frequency in children is still insignificant. WELLINGTON (1963) had one patient under 10 years of age, while HARRISON et coll. (1967) had two children of 6 and 9 years of age among 66 histologically verified cases of fibromuscular dysplasia. MACDONALD & MCMILLAN (1963), SUTTON et coll. (1963) and KAUFMANN et coll. (1964) had no children in their case materials.

There appears therefore to be justification for reporting cases with renal and extrarenal lesions, particularly as there seem to be no reports in the literature of fibromuscular hyperplasia (or dysplasia as proposed by HILL & ANTONIUS 1965) of the vertebral arteries, like one of the present cases. This child (Case 2) appears to be the first to be reported with fibromuscular hyperplasia of the ca-

Submitted for publication 15 April 1969.

## ZUSAMMENFASSUNG

Nach Lymphographie ereignete sich in einem Fall eine Fettembolie des Gehirnes und der Retina Die Komplikation der Lymphographie und das Erscheinen einer Fettembolie der Retina werden kritisch besprochen

## RÉSUMÉ

Presentation d un cas d embolies graisseuses dans la retine et dans le cerveau apres une lymphographie L auteur examine les complications de la lymphographie et le phenomene des embolies graisseuses retiniennes

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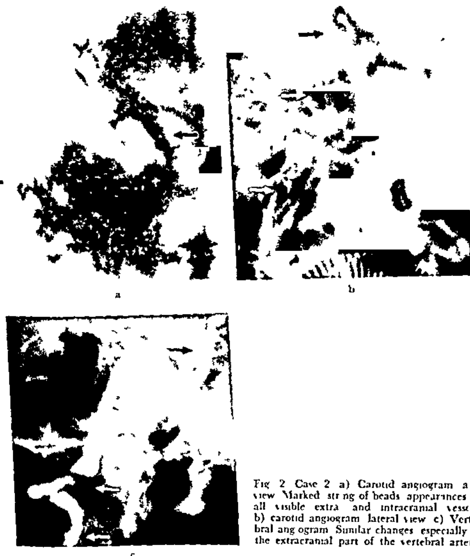


Fig. 2. Case 2. a) Carotid angiogram a.p. view. Marked string of beads appearances of all visible extra- and intracranial vessels. b) carotid angiogram, lateral view. c) Vertebral angiogram. Similar changes especially in the extracranial part of the vertebral artery.

roentgen examination of the chest was demonstrated an enlarged globular heart with a cardiothoracic ratio of 0.69.

Nephroangiographs by the transfemoral route disclosed a stenosis 8 to 9 mm long with post-stenotic dilatation of the right renal artery (Fig. 1a). The diameter of the stenosis was less than 3 mm. The hepatic artery and the small segmental arteries of both kidneys also varied in calibre with stenotic and dilated segments in conformity with the fibromuscular




Fig 1 Case 1 a) Aortography Marked narrowing with poststenotic dilatation at origin of right renal artery b) Faint indentations in prepelvic part of left renal artery with marked changes in upper and middle third of kidney

*rotid arteries, although involvement of these arteries has occasionally been ob*served in adults, mainly middle-aged women (Connett & Lansche 1965, Barker 1966, Wylie et coll 1966, Ehrenfeld et coll 1967, and Rainer et coll 1968), often combined with intracranial aneurysms and subarachnoid hemorrhage (Wylie et coll 1966) The possible relation between fibromuscular hyperplasia or dysplasia and intracranial aneurysms is unsolved

## Case reports

*Case 1* A 3 year old girl with arterial hypertension who for 2 years had had intermittent short periods of fever and several times had been admitted to a pediatric ward Hypertrophic adenoids and large tonsils were removed at the age of 2 years following a period of fatigue Slight transient proteinuria was recorded the sedimentation rate was slightly increased but the AST and ASH titers and blood chemistry were normal No changes were seen at urography The arterial blood pressure was 100 mm Hg

Nine months later the child was re admitted in an extremely bad condition with cardiac insufficiency pleurisy and pneumonia The systolic blood pressure was 210—180 and the diastolic 160—120 The child was treated with antibiotics and digitalis with good result Urography, urine and blood chemistry and the catecholeamine excretion were normal but isotope *examination of the renal function* indicated decreased function of the right kidney Ophthalmoscopy revealed a hypertonic fundus grade II with premalignant vessels at

versal vascular disease This view is supported by the present two cases, which had multifocal lesions in a great number of parenchymatous as well as parietal vessels Multifocal short stenoses with multiple mural aneurysms, producing the typical beaded appearances in the angiograms, were the most frequent findings, especially in the cerebral vessels and in the distal parts of the renal arteries with their segmental and subsegmental branches Tubular and longer stenoses prevailed in the more central parts of the arteries. The differences in type and localization of the most marked lesions explain the different symptom complexes in the present cases, as well as, for instance, in those reported by EHRENFELD et coll, STONEY et coll, and RAINER et coll The lesion which has the greatest influence on the physiologic function of an organ will be the one producing symptoms and this seems mainly to be the longer tubular stenoses This may also explain the observations of KAUFMANN et coll and the fact that some 30 to 40 per cent of all cases of fibromuscular hyperplasia are non hypertensive (ANDERSEN 1966)

The factor, or factors, that initiate the disease of the tunica media, whether infectious, toxic, stress, hormonal or metabolic, remain however unknown, and so far no explanation for the predominant occurrence in young female adults has been given Although HALPERN et coll (1965) reported renal arteriographic signs of fibromuscular hyperplasia in three hypertensive sisters, there is no established familial or hereditary tendency nor any known association with conditions such as Marfan s disease or Erdheim's cystic medionecrosis HARRISON et coll (1967) suggested that the vasa vasorum might play a significant role in the pathogenesis, and that variations in the morphologic features might be explained according to the level or extent of the vasa vasorum involvement No apparent etiologic explanation has however been found, yet, considering the multiplicity and universal distribution of the lesions, inflammatory or collagen disease may be the more probable explanation

The long term behaviour of the disease itself, and not only the symptoms aroused by it, is almost as unknown even in patients treated successfully by reconstructive vascular surgery or nephrectomy for a localized lesion Very rarely, subsequent arteriographic or functional studies have been performed, and the questions as to whether early lesions will progress once hypertension has been relieved, and whether new lesions will develop, remain as unanswered as the question of the etiologic origin

## SUMMARY

Two cases of fibromuscular hyperplasia with extensive multiple lesions in young children are reported In one of these the first to be published the fibromuscular hyperplasia included involvement of both the carotid and the vertebral arterial systems in addition to lesions of the renal mesenteric, hepatic and lumbar arteries

hyperplasia lesions described in adults (WYLIE & WELLINGTON 1960 PALUBINSKAS & WYLIE 1961, MACDONALD & MCMILLAN 1963, SUTTON et coll 1963, and PALUBINSKAS et coll 1966) (Fig 1b)

Operation revealed that the right renal artery was severely stenosed corresponding with the arteriographic findings Vascular reconstructive surgery was attempted but found impracticable, and *nephrectomy was performed in the hope that this might cure the hypertension* Microscopic examination of the kidney revealed vascular lesions as described by WELLINGTON (1963) and HARRISON et coll (1967) Postoperatively, the systolic blood pressure fell to normal values There was no cardiac insufficiency, the heart was not enlarged and the general condition was fairly satisfactory

*Case 2* An 8 year old boy who from the age of 2 years had been admitted several times to pediatric and cardiologic wards on account of a cardiac murmur and an enlarged heart Endocardial fibro elastosis (or myocardial disease of unknown etiologic origin), mainly localized to the left ventricle, was revealed by cardiac catheterization and cineangiocardiography As the boy was without major symptoms no treatment was attempted When he was 4 years old he was *thought to have psychomotor epilepsy* *EEG was abnormal* and he was put on anti epilepsy medication, to which he responded well During the last 6 months prior to the actual admission the boy seemed to deteriorate mentally and had difficulty in keeping up in sports and games with children of his on age

Two weeks prior to admission to our hospital an influenza like condition again provoked symptoms similar to those at the age of 4 years together with meningeal reactions The boy was admitted with a diagnosis of intracranial vascular malformations with hemorrhage No neurosomatic abnormality was found at an initial examination but the boy s extremities were slender and he had club fingers dome shaped nails some peripheral cyanosis and hypertension (systolic blood pressure 210—180 mm Hg)

Bilateral carotid and vertebral angiographies were performed and extensive lesions were *demonstrated in all cerebral and cerebellar vessels Innumerable small aneurysmal bulgings* of the walls of the arteries created the typical string of beads sign in the carotid and vertebral arteries and their ramifications Considerable variations in the luminal diameter were seen in the major as well as the finer vessels and the diameter of the basal ganglionic and insular ramifications of the middle cerebral artery was irregularly increased often creating an impression of angiomatous vessels Whether an angioma per se was present or the appearances were due to collaterals and dysplastic, dilated arteries and arterioles *could not be determined with certainty The branches of the external carotid arteries* also presented typical fibromuscular hyperplastic lesions a biopsy specimen was taken from the superficial temporal artery which at operation felt knotty Microscopy disclosed the characteristic appearances of fibromuscular hyperplasia (Fig 2)

Subsequent *nephro angiography revealed characteristic changes of fibromuscular* hyperplasia in both the renal and mesenteric arteries and even in the lumbar arteries Interestingly enough, the arteriographic lesions seemed more marked in vessels of minor calibre

The patient was again put on anti epileptic medication and is now well without major symptoms

## Discussion

The increasing frequency of publications of extrarenal fibromuscular hyperplasia (PALUBINSKAS & RIPLEY 1964, WYLIE et coll 1966, EHRENFELD et coll 1967, RAINER et coll 1968) indicates that fibromuscular hyperplasia is a uni

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# BALLOON CATHETERS AND THEIR PERCUTANEOUS INSERTION INTO THE VASCULAR SYSTEM

by

M HAVERLING

Methods of temporary alteration of the blood flow by balloon occlusion of large blood vessels are used in angiography in order to improve the demonstration of vessels (CARLENS et coll 1951, NORDENSTROM 1954, CANNON et coll 1956, DOTTER et coll 1959, NORDENSTROM 1962, STRAUBE & DOTTER 1963, NORHAGEN 1963, HAVERLING 1966, NORDENSTROM 1966, TAKARO 1966) Most of these investigations were made during experimental research work in animals, but a report of a fairly large number of aortographies with balloon occlusion of the human aorta was published by NORDENSTROM (1966)

Balloon catheters may be inserted into the blood vessels, either by isolation of a femoral blood vessel or percutaneously according to the techniques described by NORDENSTROM (1962) and STRAUBE & DOTTER (1963) The method requiring isolation of a blood vessel has limitations in man due to the surgical procedure This applies particularly when the catheter has to be inserted into an artery

When a balloon catheter is introduced into a blood vessel by the percutaneous methods described, the latex balloon often produces a jagged dilatation of the puncture hole This causes leakage of blood between the catheter and the vessel

Submitted for publication 6 June 1969

## ZUSAMMENFASSUNG

Es wird über zwei Fälle von weit verbreiteten multiplen Läsionen bei fibromüskularer Hyperplasie in jüngeren Kindern berichtet In einem dieser Fälle konnte zum ersten Mal über das Auftreten in den Carotis und Vertebralarterien Systeme im Zusatz zum Auftreten in den Nieren , Mesenterial , Leber und Lumbal Arterien berichtet werden

## RÉSUMÉ

Présentation de deux cas d hyperplasie fibromusculaire avec *lésions multiples étendues chez* de jeunes enfants Dans un de ces cas le premier publié, l hyperplasie fibromusculaire touchait les deux systèmes artériels carotidien et vertébral en plus des lésions des artères rénales mésentériques, hépatiques et lombaires

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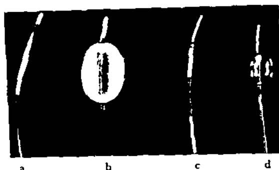



Fig 2 Catheter types A and C respectively Balloon unexpanded (a) and (c) and expanded (b) and (d)

wall of the teflon tube to permit expansion of the balloon by injection of physiologic saline via the tube (Fig 1, A and B) At its distal end, the teflon tube is blocked with a small screw The distal end of the latex balloon protrudes about 1 cm beyond the tip of the teflon tube This construction of the tip of the balloon catheter makes it easier to catheterize tortuous blood vessels An ordinary Luer-Lock one way tap may be attached to the proximal end of a catheter type A BEVEGÅRD et coll (1961) described an adapter that makes it possible to utilize two catheters simultaneously, one inside the other, during pressure recordings in the vascular system This adapter may be used for a balloon catheter type A, if a steel wire is placed in the lumen of the catheter in order to strengthen it during balloon occlusion of the aorta In this way, the balloon can be expanded without being pushed down by the blood stream through the vessel (HAVERLING 1966)

A balloon catheter of type B is made in the following way The balloon holding part of the teflon tube is cut proximal to the balloon and connected to a screw (Fig 1, B-g) This screw has two different diameters and is equipped with a tapped central hole To the proximal part of the screw are attached two plastic tubes, one inside the other, as illustrated in Fig 1, B The inner tube, of polythene,

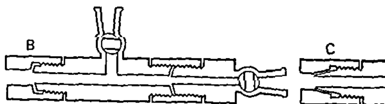



Fig 3 Special device for double lumen balloon catheters of types B and C

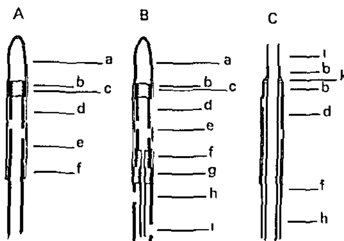



Fig 1 Distal parts of balloon catheters types A B and C a = tip of latex balloon b = distal fixation of balloon to catheter c = screw d = latex balloon e = balloon holding radiopaque tube f = proximal fixation of balloon to catheter g = metal screw with tapped channel, h = outer plastic tube, i = inner plastic tube, k — silver ring

wall and it is therefore necessary to compress the vessel above the site of the puncture throughout the examination It would appear that an insertion technique that eliminated this disadvantage would facilitate the use of temporary balloon occlusion of blood vessels in angiography

*Catheters* The balloon catheters described in this report were manufactured to meet the following requirements (1) the site of the balloon, when the catheter is placed inside the vessel, should be judged during fluoroscopy with the balloon free from contrast medium, (2) the balloon catheter should be inserted into the blood vessel with the least possible trauma and (3) no compression of the blood vessel above the site of insertion should be necessary during the examination as long as the catheter is inside the vessel

Three types of balloon catheters were made A for simple occlusion (Fig 1, A), B for occlusion and injection of contrast medium or pressure recording proximal to the balloon (Fig 1, B), and C for occlusion and injection of contrast medium or pressure recording distal to the balloon (Fig 1, C)

The balloon catheters of types A and B are of similar design The latex balloon is mounted on a radiopaque teflon tube, in order to diminish the diameter of the balloon it is stretched over the tube (Fig 2a) The balloon is attached at both ends to the tube with glue (Kontakt Lim, Casco, Stockholm) and the fusions are strengthened by a fine nylon thread wrapped around the fixation sites, this thread is held fast with a small amount of glue Two small holes are bored through the

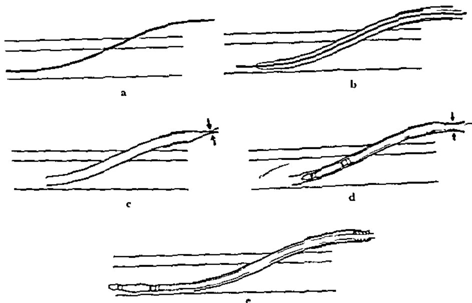



Fig 5 The different stages [illegible] d) Balloon catheter slipped through insertion tube e) Rubber plug pressed into rubber tubing or the latter clamped with forceps to unite it to the catheter

receptor The proximal end of a catheter of type C is fitted with a device similar to that used for catheters of type B (Fig 3, C)

*Balloon catheter insertion technique* All three types of the balloon catheters described are inserted into the vascular system in the same way A femoral artery or vein is punctured and the SELDINGER technique followed as far as the insertion of the catheter (Fig 5a) Instead of the catheter, a special insertion device is slipped over the guide wire This device consists of two teflon tubes, one inside the other The inner tube, called the dilatation tube, has a thick wall and an acute tip, the outer diameter is slightly larger than that of the balloon catheter The outer tube, called the insertion tube, has a thin but stiff wall A short piece of rubber tubing is attached to the proximal end of the insertion tube (Fig 6). The dilatation and the insertion tubes are introduced into the blood vessel together by slipping them over the guide wire (Fig 5b) and the dilatation tube and the guide wire are then withdrawn (Fig 5c) To avoid undue bleeding when this is done, the rubber tubing is pressed by the fingers (LINDGREN 1953) The balloon

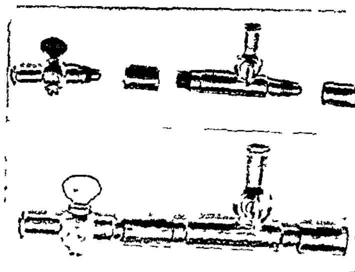


Fig 4 Special device for double lumen balloon catheters Unassembled (upper) and assembled (lower) (without catheters)

is screwed into the tapped central hole of the short metal screw which is used to connect the balloon holding the teflon tube to the proximal part of the catheter The outer tube with four or more side-holes bored distally is attached to the screw At its proximal end this type of catheter is adapted to a special device (Fig 3), made of four metal parts screwed together as illustrated in Fig 4 This device makes it possible to control both lumina of the balloon catheter simultaneously and contrast medium can be injected into the vessel proximal to the balloon occlusion through the space between the two tubes It is also possible to use this lumen to transmit the vascular pressure proximal to the balloon occlusion to a pressure receptor The lumen of the inner tube is used to expand the latex balloon

A catheter type C is made of two plastic tubes, one inside the other, the inner tube protruding beyond the tip of the outer one (Fig 1, C) The distal part of the latex balloon is attached both to the distal part of the outer tube and to the inner tube, the lumen between the inner and the outer tubes is thus occluded at the tip of the catheter The proximal part of the latex balloon is attached to the outer tube, through the wall of which two small holes are bored A communication between the latex balloon and the space between the two tubes is thus formed and the balloon can be expanded by injection of physiologic saline into the outer tube Contrast medium can be injected into the blood vessel distal to the balloon occlusion through the inner tube, or the vascular pressure distal to the balloon occlusion can be transmitted through this catheter lumen to a pressure



Fig 7 Example of use of balloon catheter type B Hepatic vein phlebogram Temporary balloon occlusion of inferior vena cava in right atrium Injection of 100 ml Urografin 60 % (14 5
a at the level of
sec with patient
or part of liver

into the vascular system The percutaneous methods described earlier have made it possible to introduce balloon catheters into the human aorta without isolation of a femoral artery However, when the catheter is introduced into the vessel, the latex balloon may be stretched downwards on the catheter, forming a cuff of uncontrolled diameter, when this is pushed through the wall of the blood vessel it tends to make the puncture hole jagged Bleeding around the catheter may occur during the examination and must be controlled by compression of the vessel above the site of the puncture The new method described makes it possible to avoid these disadvantages By utilizing dilatation and insertion tubes, atraumatic widening of the puncture hole in the blood vessel wall is ensured by the acute tip and a smooth surface Balloon catheters with two lumina reduce the number of punctures necessary The technique described may also be utilized to insert other catheters without an end hole

Balloon catheter type C can be utilized for selective occlusion of an artery,



Fig 6 Dilatation and insertion tubes assembled (upper) and unassembled (lower)

catheter is then inserted (Fig 5d) The rubber tubing is clamped with forceps in order to tighten it on to the catheter, or a rubber plug may be used for the same purpose (Fig 5e) The catheter is easily rotated, pushed up or pulled down when the forceps are released During the examination the insertion tube may be attached and fixed to the skin in the groin with plaster

*Example of the use of balloon catheters* An example of the use of a catheter type B is illustrated in Fig 7, which shows a hepatic phlebogram obtained by injection of contrast medium below a balloon on occlusion of the inferior vena cava The latex balloon was expanded inside the right atrium with 30 ml Urografin 30 %, the catheter then being pulled down against the inferior vena cava One or two seconds later 100 ml Urografin 60 % were injected via the space between the two tubes at a rate of 14 5 ml/sec The injection of contrast medium into the inferior vena cava was performed at the level of the hepatic veins No other technical procedures were utilized Two exposures per second for ten seconds were obtained, the patient was fully conscious and in supine position throughout the examination The balloon was emptied quickly after the last exposure

## Discussion and Conclusions

The catheters described are made in such a way that it is possible to judge the site of the balloon mounted at the tip of the catheter during fluoroscopy without filling it with contrast medium

Catheterization following isolation of blood vessels is still utilized in angiography, although satisfactory percutaneous catheter insertion methods have been described (LINDGREN 1953, SELDINGER 1953, GIDLUND 1956), in radiology of today percutaneous insertion of catheters should be the one of choice (GREITZ & LINDGREN 1961) This is also the case when balloon catheters are to be inserted

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such as the renal artery (HAVERLING 1969) This suggests future use of balloon catheters for controlled selective arterial occlusion, i e during ischaemic treatment of malignant tumours

The bolloon catheters described are 'home-made' but it is hoped that they will become available commercially

## SUMMARY

New types of balloon catheters and a percutaneous insertion technique for the occlusion of vessels in angiography are described Selective occlusion of an artery for the ischaemic treatment of malignant tumours is mentioned as an outcome of the method

## ZUSAMMENFASSUNG

Neue Typen von aufblasbaren Kathetern und eine perkutane Einfuhrungstechnik zur Okklusion von Gefassen wahrend Angiographie werden beschrieben Die Methode ermoglicht selektive Okklusion einer Arterie fur die ischamische Behandlung maligner Tumoren

## RÉSUMÉ

L'auteur decrit un nouveau type de sonde a ballonnet et une nouvelle technique d introduction percutanee pour l occlusion des vaisseaux au cours de l angiographie L occlusion selective d une artere pour le traitement ischemique des tumeurs malignes est signalee comme une application de cette méthode

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Fig 1 Left selective renal angiography one week after kidney puncture Small aneurysm in upper pole with rapid contrast filling of a vein



Fig 2 Left selective renal angiography one week after kidney puncture Aneurysm in lower pole and good contrast filling of the renal vein.

rabbits, the weights of the animals varied from 2 0 to 3 0 kg and the ages from 10 to 12 months Percutaneous puncture of one of the kidneys was made under intravenous pentobarbitone (Mebumalnatrium, ACO, Sweden) The needle had an outer diameter of 0 4 mm, which for the rabbit's kidney is comparable with the diameter of the needle used in human renal biopsies Only one puncture was usually made although two or three regions of the kidney were sometimes selected Selective catheterization of the renal artery from the femoral artery (ADAMS et coll 1965) was made with a radiopaque polythene catheter (OPP 60, Portex, England), outer diameter 1 15 mm, inner diameter 0 75 mm The catheterization was aided by magnification fluoroscopy (EKELUND & OLIN 1970), the contrast medium used being metrizoate sodium (Isopaque 350, Nyco, Norway), which was injected at a suitable and constant rate with an infusion machine (CLEMENTZ & OLIN 1963) The angiograms were made on industrial film, Structurix D4 (Agfa Gevaert) at a focus-film distance of 40 cm, mAs 20, kV 90 and 0 04 sec The film, beneath which is a thin sheet of lead, was placed in close contact with the animal Angiographies were usually performed one or two weeks after the puncture, followed in some animals by a second angiography four weeks after the puncture

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# ARTERIOVENOUS FISTULAE SECONDARY TO RENAL BIOPSY

## An experimental study in the rabbit

by

L EKELUND

Arteriovenous fistulae of the kidney may occur secondary to needle biopsy (BOIJSEN & KOHLER 1962, FERNSTROM & LINDBLOM 1962, BLAKE et coll 1963, BENNETT & WIENER 1965, RILEY 1965, NILSSON & ROSS 1967) Even open renal biopsy may produce a renal aneurysm with fistula (FAUST 1968) The frequency is supposed to be low, which is surprising since the vascular richness of the kidney, with the consequent possibility of injury to an artery and a vein in close relationship, ought to favour fistula formation BENNETT & WIENER, however, reported 9 arteriovenous fistulae and 2 arterial aneurysms following 58 renal biopsies An attempt to evaluate how often an arteriovenous fistula develops secondary to needle biopsy of the kidney thus appeared justified

*Material and Methods* The kidney on one side was punctured and selective renal angiography was performed at different periods after the puncture in 36

This study was supported by a grant (No B69 23X 605 03) from the Swedish Medical Research Council Submitted for publication 17 July 1969

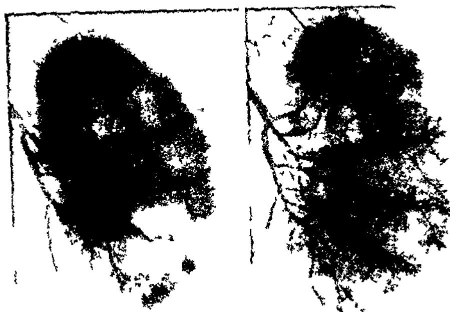


Fig 5 Left selective renal angiography one week after kidney puncture Fistula formation between middle and upper pole

Fig 6 Same case as in fig 5 Four weeks after puncture Closure of fistula

connection with repeat kidney puncture produced general intrarenal artery spasm and extravasation of contrast material

Four cases with proved fistulae had a second angiography four weeks after the puncture In two of these rabbits the arteriovenous fistula had closed completely, in one it had diminished considerably, and in the fourth case it was of roughly the same size as at one week after puncture (Figs 5 and 6)

All the animals were in good condition during the experiment No cases of macroscopic haematuria were observed although these were not especially sought

## Discussion

Reports in the literature of renal arteriovenous fistulae following renal biopsy are few The first was reported in 1962 The largest material was presented by BENNETT & WIENER and consisted of 9 intrarenal arteriovenous fistulae and 2



Fig 3 Left selective renal angiography one week after kidney puncture Arterio venous fistula with good contrast filling of the renal vein This rabbit was pregnant



Fig 4 Right selective renal angiography one week after kidney puncture Arteriovenous fistula in middle part of the kidney with contrast filling of the renal vein as well as the inferior vena cava Insufficient filling of glomeruli distal to the shunt

## Results

Fistulae secondary to the puncture developed in 16 (44 %) of the 36 cases, the size of the shunt varying The fistula sometimes orginated from a small intrarenal artery aneurysm (Fig 1) while in others it had a width of up to 2 3 mm, good contrast filling of the renal vein as well as the inferior caval vein was obtained in the latter instance (Figs 2, 3, 4) The fistulae always appeared in the medulla of the kidney and never in the cortex Infarction peripherally to the shunt never occurred but insufficient filling of glomeruli was often evident Insufficient filling of the arteries of other parts of the kidney was noted due to the shunting in cases with large fistulae

Spasm of the renal artery occurred at angiography in 3 cases of arteriovenous shunt The lumen of the renal artery varied between 1 5 and 2 0 mm in the arteriovenous shunt cases as compared with a variation of from 1 6 to 1 8 mm in the remaining material The normal lumen of the renal artery in the rabbit is 1 7 to 1 8 mm (IDHBORN 1956), there is thus a slight widening of the renal artery in most of the cases of arteriovenous fistulae

In a case not included in the material renal angiography, performed in direct



Fig 5 Left selective renal angiography one week after kidney puncture *Fistula formation* between middle and upper pole



Fig 6 Same case as in fig 5 Four weeks after puncture Closure of fistula

connection with repeat kidney puncture, produced general intrarenal artery spasm and extravasation of contrast material

Four cases with proved fistulae had a second angiography four weeks after the puncture In two of these rabbits the arteriovenous fistula had closed completely, in one it had diminished considerably, and in the fourth case it was of roughly the same size as at one week after puncture (Figs 5 and 6)

All the animals were in good condition during the experiment No cases of macroscopic haematuria were observed although these were not especially sought

## Discussion

Reports in the literature of renal arteriovenous fistulae following renal biopsy are few The first was reported in 1962 The largest material was presented by BENNETT & WIESER and consisted of 9 intrarenal arteriovenous fistulae and 2

renal aneurysms out of 58 renal biopsies. The reason so few cases have been reported is that angiographic examinations are rare in relation to the performance of renal biopsy and that cases in which biopsy has been performed are seldom followed up with renal angiography. Angiography is sometimes performed in an unsatisfactory manner — there is reason to believe that a small fistula may be overlooked if only aortography and not a truly selective examination is performed. Another reason may be a tendency of the fistulae to spontaneous healing. BENNETT & WIENER described the disappearance of the fistula in 3 cases. The fistula in the present material healed in 2 out of 4 cases, checked by angiography four weeks after puncture. (Further investigation is in progess to evaluate the frequency of spontaneous healing of fistulae.)

BLAKE et coll. presented 2 cases in which renal angiography was performed because of a bruit over the kidney with the fistula. In 60 other cases in which no bruits were heard, angiography was not performed, and these cases were considered free from fistula formation. Some of the fistuale in this experimental material are certainly too small or too large to give an audible bruit, and there is reason to believe that this sign is not sufficient for establishing the diagnosis.

The number of arteriovenous fistulae in this experimental work is strikingly large. It might be that this may have been due to the lumen of the needle used, the outer diameter of which was 0.4 mm. The needle for human percutaneous renal biopsies has an outer diameter usually ranging from 1.5 to 2.0 mm. The rabbit's kidney has a length of from 3.0 to 3.5 cm and the human kidney a length of from 11.0 to 11.8 cm (HOFFMANN). The diameter of the needles are thus comparable in relation to the length of the kidney. Furthermore, the diameter of the renal artery in the rabbit is 1.7 to 1.8 mm, as compared with 4.6 to 9.7 mm in man (EDSMAN 1957).

Arteriovenous fistulae appear in blunt trauma as well as after perforating trauma, MUTH & OLIN (1968) reported 4 arteriovenous fistulae in 16 such cases.

There seems to be a predisposing factor in the development of human renal arteriovenous fistulae following renal biospsy, namely hypertensive disease. The hypertension may act through its haemodynamic effects or by the nephrosclerosis which it causes; in this experimental material no hypertension was provoked. Other factors that may by of importance are age and sex (hormonal influence). The animals in this experiment were young and the sex ratio was almost 50: 50. One female rabbit in which a fairly large fistula developed was found to be pregnant.

Finally it should be stated that congenital arteriovenous fistulae may occur in the kidney although apparently rarely (LOVE et coll. 1965).

The investigation points to the fact that arteriovenous fistulae following renal biopsy are more common than usually believed and that for their proper recogni-

tion renal angiography should follow renal biopsy more often Biopsy should however precede angiography in cases in which both renal biopsy and angiography are planned in the examination

As mentioned above, investigation is in progress to evaluate the frequency of spontaneous fistula healing Investigations concerning fistula formation in animals with experimental hypertension are also planned

## SUMMARY

An experimental study in the rabbit of the development of renal arteriovenous fistulae following kidney puncture is presented Selective renal angiography was performed in 36 rabbits in which kidney puncture had been performed previously Arteriovenous fistulae were demonstrated in 16 cases (44 per cent)

## ZUSAMMENFASSUNG

An Kaninchen wurde die Entwicklung von arteriovenosen Fisteln nach Punktur der Nieren experimentell studiert An 36 Kaninchen wurde selektive renale Angiographie nach vorheriger Punktur der Niere vorgenommen In 16 Fallen (44 Prozent) konnten arteriovenose Fisteln festgestellt werden

## RÉSUMÉ

Presentation d une etude expérimentale sur le lapin concernant l apparition de fistules arterio veineuses apres ponction renale l auteur a fait une angiographie rénale sélective sur 36 lapins qui avaient subi auparavant une ponction rénale Il a *mis en evid nce* des fistules artério-veineuses rénales dans 16 cas (44 pour cent)

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FROM THE DEPARTMENTS OF PEDIATRIC PATHOLOGY (DIRECTOR B IVEMARK), AND DIAGNOSTIC RADIOLOGY (DIRECTOR B NORDENSTROM), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

# ROENTGENOLOGIC DIAGNOSIS OF POLYCYSTIC KIDNEY AND MEDULLARY SPONGE KIDNEY

by

B I IVEMARK, C LAGERGREN and N LINDVALL

GRUBER (1927) compared the general appearances of polycystic kidneys to a sponge although today the term medullary sponge kidney is used for a specific cystic renal condition with characteristic roentgen and histologic appearances (EKSTROM et coll 1959, CACCHI 1960) Difficulties in the roentgen differential diagnosis seem to occur only in cases of polycystic renal disease of less common appearance The purpose of this paper is to discuss the histologic and roentgen features of these two conditions

The study was based on the roentgen and histologic examination of 9 cases of polycystic kidney and 120 cases of medullary sponge kidney The microscopy studies were based upon biopsies and resections as well as upon autopsy cases The age ranges at the time of examination were 1 to 50 years for polycystic kidney and 17 to 50 years for medullary sponge kidney

## Results

*Polycystic kidney, described by* POTTER *as type* 3 (OSATHANONDH & POTTER 1964), is considered to be due to multiple abnormalities of development and

This investigation was supported by grants from Svenska Livforsakringsbolags namnd for medicinsk forskning Submitted for publication 27 May 1969

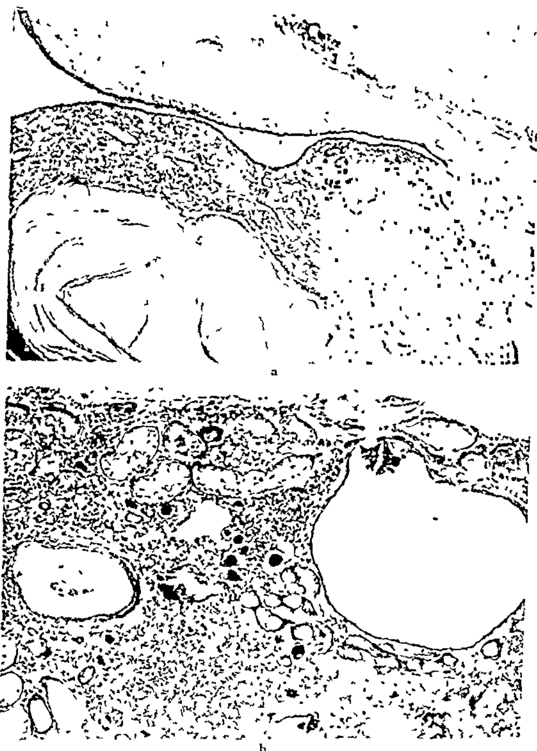



Fig. 1. Polycystic kidney (Potter type 3). a) Compression of calyceal recess by large medullary cysts. b) Cortical part with one glomerular cyst (right) and one tubular cyst. Increased interstitial fibrous tissue and some normal proximal tubules present. Haematoxylin eosin. × 75.

cystic changes may involve any part of the nephron (Figs 1 to 6) The lesion is usually but not always bilateral Such kidneys are generally larger than normal but increase in size with advancing age from progressive growth of the cysts. The degree of enlargement depends upon the age of the patient, the number of renal tubules involved, and the amount of fluid in the cysts, the cysts are ordinarily present throughout the renal parenchyma The microscopy appearances vary in relation to the degree of abnormality Normal glomeruli, normal convoluted tubules and collecting tubules are mixed with cystic dilatation of glomeruli and all parts of the collecting ducts and nephrons This irregular intermixture is characteristic of the condition There is also increase in the amount of interstitial connective tissue *Primitive ducts, ductules or cartilage characteristic of polycystic* renal dysplasia are not seen (ERICSSON & IVEMARK 1958)

Cases of polycystic kidney type 3 run a variable clinical course, depending upon the extent of renal involvement Progressive renal failure, arterial hypertension and diffuse renal pain have constituted indications for urography One of the present cases was discovered during routine examination for trauma A few cases, apparently with early manifestations of polycystic disease (in childhood and early adolescence) have facial features resembling those of POTTER's syndrome (hyper telorism low set ears and hypognathia) In none of the present cases was a family history of renal disease recorded

Roentgenography in adults usually discloses enlarged kidneys The urographic appearances early in the disease are normal but contrast density *decreases with* progressive renal insufficiency The calyces, the necks of the calyces *and the pelvis* may be deformed by cysts, the calyces are often club-shaped and lack papillary impressions Some of the pyramids contain cavities *that primarily* fill with contrast medium during urography These cavities *are usually few and* irregular, occasionally resemble dilated collecting tubules and may contain calculi Free concretions are sometimes present In addition *larger cysts occur* similar to those found in the common adult polycystic kidney The combination of all these forms of cysts *facilitates the* diagnosis The ureters and bladder present no changes Nephroangiography will demonstrate *cysts of* varying size throughout the parenchyma as in the adult polycystic kidney

*Medullary sponge kidney* (EKSTROM et coll 1959) This appears to be a congenital malformation (Figs 7 8) The kidney may be normal in size, enlarged or atrophic largely *dependent on the extent* and stage of the accompanying pyelonephritis The most striking pathologic feature is the presence of multiple small cystic cavities confined to the pyramids and consisting of both cysts and dilated collecting tubules (Fig 7) *some* of the cysts may communicate with the tubules or with one another These medullary cysts may contain calculi, usually




Fig. 2. Bilateral polycystic kidneys (POTTER type 3). a) Urography at the age of 9 years. Both kidneys contain numerous irregular contrast filled cavities, some of them located in the cortex. Slight deformation of some calyces. b) Another case. Both kidneys contain irregular contrast filled cysts in the pyramids and larger cysts in the cortex. Haematuria was the presenting symptom.




Fig 3 Bilateral polycystic kidneys (POTTER type 3) Renal colic for several years a) Several calculi in the enlarged kidney b) Urography Typical irregular contrast filled medullary cavities in the lower pole Deformation of calyces and necks of calyces caused by large cysts

of mixed calcium phosphate Cortical cysts are not a part of the condition, but the cortex may be narrow and fibrotic owing to concomitant pyelonephritis The loops of Henle are not hyperplastic and do not have basement membrane thickening — unlike in the nephronophthisic kidney Large cysts compressing calcyceal recesses do not occur in the medullary sponge kidney

Medullary sponge kidney often produces renal colic and gross haematuria and sometimes pyelonephritis

The radiologic appearances are highly characteristic with the presence of cavities of varying size and extent in the pyramids, the cavities are filled primarily with contrast medium during urography and are regularly shaped, whether oval or rounded The cysts vary in number from a few to many and often contain calculi, their number likewise varying from a few to several hundred If the changes are present throughout the entire medulla, the kidney may be enlarged. No changes are evident in the films in mild cases The nephroangiographic appearances are normal

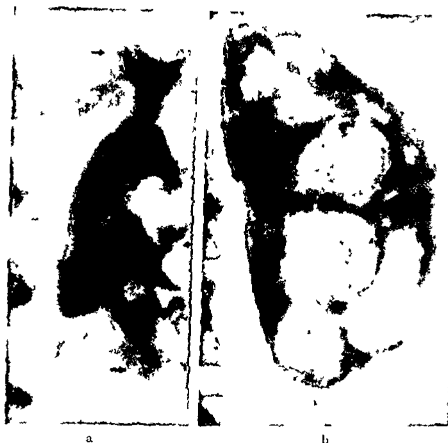



Fig. 4. Unilateral polycystic kidney (POTTER type 3). Haematuria after trauma of left kidney region. a) Urography. Enlarged kidney with irregular contrast filled medullary cavities (arrows). Deformation of calyces and necks of calyces by large cysts. b) Late nephroangiographic phase. Multiple filling defects in the cortex indicating cysts.

## Conclusion

The histologic appearances of polycystic kidneys in the present material correspond to the description by OSATHANONDH & POTTER (1964) as 'type 3 due to multiple abnormalities of development', these authors stated (p. 512) that the *type 3 polycystic kidney is the variety generally designated as* polycystic kidney of the adult.

However, the present histologic, roentgenologic and clinical findings in the polycystic kidneys *fail to support this view. Common so-called adult* (familial) polycystic renal disease presents different histologic and radiologic appearances, without structural evidence of malformation of the renal parenchyma, without contrast-filled cavities at urography but with the presence of parenchymal calcifi



Fig 5 Bilateral polycystic kidneys (POTTER type 3) Urinary tract infection Urography Enlarged kidney with small irregular contrast filled medullary cavities in some pyramids (arrows) Calyces deformed by larger cysts



Fig 6 Bilateral polycystic kidneys (POTTER type 3) Renal insufficiency and hypertension Pyelography Kidney normal in size The contrast filled medullary cavities predominate

cations both radiologically and histologically (IVEMARK & LINDBLOM 1958) Furthermore, there was no family history in the present cases nor in those of OSATHANONDH & POTTER This is in sharp contrast to the common adult polycystic kidney The writers therefore consider the Potter type 3 polycystic kidney as a mixture of the common adult familial polycystic kidney and an apparently non familial separate entity The discrepancy between the Potter classification and the clinico-radiologic appearances of polycystic kidneys has also been stressed by EBEL & OLBRING (1969) The present nine cases of polycystic kidneys tally well with those of the true non familial Potter type 3 kidney and the series contains no common adult polycystic kidney cases

The authors have considered four renal lesions with medullary cysts (Table) They are separate entities although they may resemble each other However,




Fig. 4. Unilateral polycystic kidney (POTTER type 3). Haematuria after trauma of left kidney region. a) Urography. Enlarged kidney with irregular contrast filled medullary cavities (arrows). Deformation of calyces and necks of calyces by large cysts. b) Late nephroangiographic phase. Multiple filling defects in the cortex indicating cysts.

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Fig 7 Medullary sponge kidney Ectatic and cystic collecting and papillary ducts No calculi present in this part of the kidney Haematoxylin eosin ×12




Fig 8 Unilateral medullary sponge kidney a) Group of rounded small calculi in the enlarged upper pole b) Urography Typical cavities in the enlarged papillae of the upper pole, calculi lie in some of the cavities

**Table**

*Differential diagnosis of four renal medullary cystic lesions*

| | POTTER, type 3 | 'Common adult polycystic kidney' | Medullary sponge kidney | Nephronophthisis |
|---|---|---|---|---|
| Age | Infants, adults | Adults | Adults | Children adolescents |
| Cavities (urography) | Few, irregular | Not present | Numerous and regular | Not present |
| Nephroangiography | Numerous defects | Numerous defects | Normal | Atrophy, no defects |
| Histology | Small and large cysts of cortex and medulla increased connective tissue, sometimes calculi | Large cortical cysts sometimes with blood and calcifications, no increase in connective tissue | Cystic and ectatic collecting and papillary ducts no cortical cysts calculi in some cysts | Medullary and juxtacortical cysts tortuous loops of Henle with basement membrane thickening atrophy |
| Clinical features | Variable, renal pain progressive renal failure occasionally 'Potter facies' | No Potter face, renal colic, haematuria, intracranial aneurysms, progressive renal failure, hypertension | Renal colic gross haematuria pyelonephritis | Polydipsia polyuria final azotaemia no proteinuria haematuria or hypertension |

these conditions are merely examples of a medullary cystic change that may occur in other states, e g trisomy 13—15 (GUSTAVSSON et coll 1962) and nephronophthisis which is even called 'medullary cystic disease' (BROBERGER et coll 1960 IVEMARK et coll 1960, STRAUSS & SOMMERS 1967)

Medullary sponge kidney is easy to differentiate radiologically from tuberculosis, renal papillary necrosis and various forms of nephrocalcinosis (CACCHI 1960, EKSTROM et coll 1967) It may, however, be difficult to distinguish between medullary sponge kidney and polycystic kidney type 3, but certain radiologic details differ For example, the shape and number of the cavities are of importance They are numerous and regular in outline in the medullary sponge kidney, while they are usually few and irregular in polycystic kidney in which the small medullary cysts are accompanied by cortical cysts The calyces and the papillae in medullary sponge kidney are normal or enlarged The calyces of the polycystic kidney are often club shaped and lack normal papillary impressions

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EBEL et coll described various polycystic renal changes in infants and children and their radiologic illustrations revealed several cases with the same appearances as in the present cases of polycystic kidney However, they did not group these together but separated the infantile from the adolescent cases It is also of some interest that as early as 1960 REILLY & NEUHAUSER described cases of renal tubular ectasia in cystic disease, some of which had the same roentgen appearances as the present polycystic kidney cases

The nephroangiographic differences between medullary sponge kidney and polycystic kidney type 3 are still more obvious The former presents normal appearances while in polycystic kidney type 3 there are numerous defects of varying size in the cortex as in the common adult polycystic kidney, caused by the cortical cysts Despite the similarity in nephroangiographic appearances in these two latter lesions, urographic differences are apparent The common adult polycystic kidney contains no contrast-filled cavities outside the calyces and the calcifications are parenchymal, while in polycystic kidney type 3 concretions are present within the cavities

It has recently been suggested on the basis of the findings in one case (NEMOY & FORSBERG 1968) that polycystic change may occur in both the cortex and medulla when radiologic evidence of medullary sponge kidney is associated with enlarged kidneys This was not confirmed in the enlarged kidneys of the present series of 120 cases of medullary sponge kidney

The group of medullary cystic renal changes also includes *nephronophthisis*. The location and type of cysts in this condition make it theoretically possible to demonstrate them at urography, this could, however, not be confirmed in our studies

## SUMMARY

The radiologic and histologic differential diagnoses in two renal medullary cystic conditions — *polycystic kidney (Potter type 3) and medullary sponge kidney* — are described

## ZUSAMMENFASSUNG

Die radiologische und histologische Differentialdiagnose in zwei medullaren Zystenerkrankungen polyzystische Niere (Potter Typus 3) und medullare Schwammniere wird beschrieben

## RÉSUMÉ

Description du diagnostic différentiel radiologique et histologique de deux affections kystiques de la médullaire rénale le rein polykystique (Potter type 3) et le rein en éponge

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## ZUSAMMENFASSUNG

*Die radiologische und histologische Differentialdiagnose in zwei medullaren Zystenerkrankungen polyzystische Niere (Potter Typus 3) und medullare Schwammniere wird beschrieben.*

## RÉSUMÉ

Description du diagnostic differentiel radiologique et histologique de deux affections kystiques de la medullaire renale: le rein polykystique (Potter type 3) et le rein en éponge

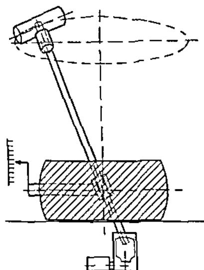


Fig 1 Principles in determining the height of the layer The image intensifier takes the position of the cassette during fluoroscopy

Mention should be made of the Pohl patent (1937) according to which the tomoscopic im[illegible]
of rotating m[illegible]
with a rotatin[illegible]
the cathode beam changes the height of the layer correspondingly These and similar systems are characterized by the fact that all but the image shadows in the pivot plane are blurred just as in a tomographic film.



Fig 2 Dens epistropheus tomographed after centering and standstill on the monitor

FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF J FRIMANN-DAHL), ULLEVÅL SYKEHUS, OSLO, NORWAY

# IMMEDIATE CENTERING AND TOMOGRAPHIC CUT LOCALIZATION BY MEANS OF ROENTGEN TELEVISION

by

J FRIMANN-DAHL and H B KUHL

Positioning and ascertaining the correct pivot plane for tomographic sectioning is often a difficult as well as a time-consuming procedure Several methods that reduce the number of trial exposures necessary for arriving at the desired section have been described in the past Estimation of the correct level by applying anatomic knowledge is common For example, a tomogram through the human hip joint will usually be located approximately 8 cm above the table top with the patient supine Multisection tomography can also be used for estimation of the correct level, several cuts being taken through the region to be examined However, the former method gives only a coarse approximation, and the latter produces considerable unsharpness due to the use of intensifying screens of varying speeds

Trigonometric methods for ascertaining the desired layer have been tried Exposures in two extreme tube positions are taken, and the level sought is derived from the distance the object has wandered on the screen The Siemens Universal Planigraph utilizes this method Various tomoscopic devices have been suggested and described, but to our knowledge none of these has been used in practice

Submitted for publication 15 July 1969



Fig 4 Tomogram of fractured L1 in a heavy subject



Fig 5 Single tomogram of gallstone centered and arrested on the television screen

rotation per 2 seconds) with an angle of cut of 30° The correct depth of sectioning is then found by moving the fixed pivot plane up or down until the movement of the examined object on the monitor ceases, when this occurs it must correspond to the pivot plane, as explained above After a little experience, the observer may perform the procedure with only 5 to 10 seconds of fluoroscopy The image intensifier is then replaced by a cassette, the object being centered and at the correct level

Experience with the method has been promising and it has proved satisfactory for many diagnostic purposes Its application is easiest and most striking when immovable objects such as bony structures are examined The dens epistropheus, which is difficult to display in conventional films could be clearly demonstrated in a tomogram, well centered and in the correct plane (Fig 2) Similar results may be obtained in the examination of the hip, the desired cut is particularly easy to find in nailed hips (Fig 3) In obese patients certain projections, for example a lateral view of the spine, may present some difficulty The centering and selection of the correct cut is however usually possible (Fig 4)

Problems may arise in the examination of structures that move with respiration for it may be difficult to decide whether the movements are physiologic or due to the tomographic projection These may be overcome if the patient is cooperative



Fig 3 Tomogram of nailed hip (pseudarthrosis)

A new method utilizing a specially designed rotational tomograph has been tried by the authors The unit is distinguished by the fact that any complicated system of rotating mirrors or the like has been avoided The method makes use of television monitored fluoroscopy for direct visual location of the tomographic pivot plane and in its present stage of development has yielded satisfactory results

During adjustment of the depth of the desired pivot plane, an image intensifier mounted under the bucky diaphragm is substituted for the cassette The image intensifier thus follows the rotation of the diaphragm, synchronous with the movement of the roentgen tube, exactly as the cassette would have done As a result of this arrangement of tube and intensifier, the object shadows that are not in the pivot plane move on the television monitor at varying speeds The movement and rate of travel of each image detail will be dependent upon the distance of the object from the fulcrum and only the image of an object detail located in the pivot plane will remain stationary on the television screen The image details that are 'frozen' at any given time are easily discernible

In the examination of a patient the structure is located on the monitor for the examination, as usual The tomograph is then set in motion (approximately one

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# L'ARTERIOGRAPHIE APRÈS CATHETERISME PERCUTANE PAR VOIE ARTÉRIELLE AXILLAIRE

par

J F HUGUET et B NAVARRO

NEWTON en 1963 et ROY en 1965 sont les premiers a pouvoir faire etat d une serie importante de catheterismes axillaires pour explorer le coeur gauche et le systeme arteriel Seduits par cette voie d abord nous l avons utilisee frequemment. Nous voudrions apporter notre contribution au developpement de cette methode Elle ne nous parait pas en effet avoir ete utilisee suffisamment pour les radiographies vasculaires Connaissant bien maintenant ses inconvenients et ses grands avantages nous repeterons sur cette rive de l Atlantique ce que dit ROY a Montreal et nous apporterons notre experience

Nous envisagerons successivement la technique du catheterisme axillaire les applications les resultats et la critique de la methode

## Techniques, materiel, et mise en place de la sonde

*Preparation du malade* Il ne nous parait pas bon que le patient soit strictement à jeûn nous preferons qu il prenne une boisson quelle qu elle soit pourvu *qu elle soit abondante avant de se presenter a l hopital*

En effet nous pensons avec DUQUESNEL que la deshydratation consecutive a

Soumis à la Rédaction le 9 janvier 1969

and able to hold his breath for the necessary period of time. A gallstone can easily be centered and a cut taken through its equator (Fig. 5). Most difficult, if not impossible, is the examination of structures such as the biliary ducts, which are only faintly depicted on the screen; conventional methods with preliminary films for orientation are then probably better. The limiting factor in the use of the method in the examination of small objects is the contrast and resolution of the picture. With improvements in television, observation of detail that is only poorly demonstrated today may be greatly facilitated.

## SUMMARY

A new method for selecting the depth of tomographic section by direct visual monitoring is described The tube and the image intensifier move synchronously during fluoroscopy, and the movement of the object is followed on the television screen until it remains stationary The correct depth for the tomogram is thus obtained

## ZUSAMMENFASSUNG

*Eine neue Methode zur Bestimmung der Tiefenwahl fur Tomographieschnitte* mittels Bildverstarkerdurchleuchtung wird angegeben Rohre und Bildverstarker bewegen sich synchronisiert wahrend der Durchleuchtung und die Bewegung des Zielobjektes wird solange auf dem Schirm verfolgt bis es zum Stillstand kommt Mit diesem Vorgehen erhalt man die richtige *Schnitt Tiefe*

## RÉSUMÉ

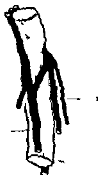
Description d'une nouvelle methode pour choisir la profondeur d'une coupe tomographique directement par radioscopie televisee Le tube et l'intensificateur d'image se déplacent de façon synchrone pendant la radioscopie et on suit le mouvement de l'objet sur l'écran de *télévision jusqu à ce qu'il reste stationnaire On obtient ainsi la profondeur correcte* pour la coupe tomographique

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F g ? Rapport de l artère ax lla re et du plexus brachial Les deux rac nes du méd an se rejo gnent (1) et le cut tal (3) se d r ge entre artères et eine

jacent Il faut si possible etre au dela des arteres circonflexe et scapulaire inferieure qui peuvent sinon etre ponctionnees inutilement on pense aussi qu elles peuvent aider en cas de thrombose a la revascularisation d aval (Fig 1)

Le point de ponction apres palpation minutieuse est repéré L anesthesie locale doit etre abondante 20 ml de novocaine 1 % il faut qu elle soit profonde Elle peut entraîner un engourdissement temporaire de la main

La ponction arterielle est faite avec le trocart apres reperage des battements arteriels reperage au doigt puis a la pointe du trocart qui transmet le pouls. Il faut eviter les ponctions iteratives qui risquent de blesser l artere et les branches du plexus brachial (une bonne localisation prealable est donc *essentielle*)

Lorsque le sang jaillit rythme et avec un jet de plusieurs *dizaines de centimetres* le guide est mis en place sous controle televise, on le pousse jusqu a la crosse aortique si possible et on enleve le trocart Il faut *bien comprimer la zone* de ponction a ce moment là pour eviter que l aisselle ne se *remplisse* de sang La sonde une fois mise en place il n y a plus de saignement possible La sonde est alors enfilee sur le guide on peut, sans que cela soit oblige faire une moucheture au bistouri *sur* la peau

Avant de franchir la peau et d introduire la *sonde dans l* artere on s assure de la liberte de la tete du *guide afin qu il* ne perfore pas une tunique sur laquelle il bute Sous controle scopique on fait alors cheminer la sonde et le guide de concert Quand la sonde est en place *il faut retirer le* guide et bien rincer la sonde pour la laisser toujours remplie de serum et non de sang *Ce serum sera* discrètement heparıné quelques gouttes dans 250 ml de serum

*Les aleas possibles* Les deux racines *du median* se rejoignent au niveau meme de la zone ponctionnee et le médian couvre l artère Le cubital est lui aussi tres proche Il est donc frequent que le *sujet* accuse des douleurs en eclairs dans



Fig. 1. Radiographie de la position du trocart avant l'introduction du guide. Le point de ponction de l'artère axillaire se fait sur le plan dur de la tête humérale si possible en amont des artères circonflexe et scapulaire inférieure qui peuvent être une voie de revascularisation éventuelle.

un jeûne prolongé (parfois plus de 12 heures quand le patient est vu au milieu de la matinée) amène une hémo-concentration, facteur favorisant les thromboses. Aucune prémédication n'est faite à part exception. Nous expliquons en détail au patient les manoeuvres pratiquées, et attendons de lui qu'il nous fasse part de ses réactions. Quand nous sommes amenés à calmer le patient, nous nous adressons au Dolosal ou au Valium par voie intra-veineuse ou par la sonde du cathétérisme.

Le patient en décubitus présente l'aisselle en mettant sa main sous la tête, aisselle rasée et désinfectée.

*Matériel.* L'examen ne peut être fait sans amplificateur et télévision. Le trocart que nous employons est du type Seldinger de diamètre variable (Seldinger 1953, Ödman 1956). Les sondes sont de plusieurs types suivant l'examen, nous employons souvent les Cordis Ducor bleues No 8, préformées et serties. La plus grande attention doit être portée au guide qui doit être adapté à la sonde en calibre et longeur et de bonne qualité.

*Mis en place de la sonde.* La ponction se fait dans le sommet de l'aisselle sous l'auvent pectoral à la hauteur de la tête humérale qui fait un plan dur sous-



Fig 2 Rapport de l artère axillaire et du plexus brachial Les deux racines du median se rejoignent (1) et le cubital (3) se dirige entre arteres et veine

jacent Il faut si possible etre au dela des arteres circonflexe et scapulaire inferieure qui peuvent sinon etre ponctionnees inutilement on pense aussi qu elles peuvent aider en cas de thrombose a la revascularisation d aval (Fig 1)

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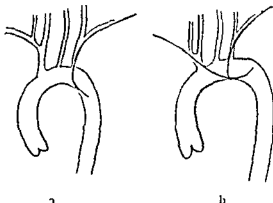



Fig. 3. Si la crosse est normale (a), le guide descend tout droit dans l'aorte descendante. Si la crosse est *déroulée* (b), le guide doit faire un angle aigu pour aller dans la descendante, alors qu'en arrivant par le tronc artériel brachiocéphalique l'angle est plus favorable.

l'avant-bras et la main au moment soit de l'anesthésie mais surtout de la ponction. Ce risque est difficilement évitable étant donné les rapports anatomiques. Il faut donc éviter les piqûres itératives (Fig. 2).

Il peut se faire que l'on ait un jet de sang bien rythmé mais que l'on ne puisse pousser de quelques millimètres le trocart, ou que le guide bute quand on l'introduit. Il s'agit alors de la scapulaire inférieure et il faut recommencer la ponction après avoir comprimé soigneusement cette artère.

Le cheminement du guide peut être stoppé, ou dans une boucle artérielle (coude de la sous-clavière, boucle du tronc artériel brachiocéphalique) — il faut faire quelques manoeuvres prudentes, uniquement avec la partie souple du guide *bouclé si possible* et ne pas insister — ou par une sténose.

Il peut être impossible de faire passer le guide dans la partie descendante de la crosse. Par voie gauche, si l'aorte est déroulée, si la sous-clavière fait un angle aigu avec la crosse, le guide ne pourra remonter dans la crosse (Fig. 3). Il faut essayer alors un guide très courbé à son extrémité qui peut réussir à franchir le trajet en baïonnette. Par voie droite on peut passer dans l'aorte decendante. Nous le faisons lorsqu'il existe une sténose sous-clavière gauche ou lorsque la crosse nous paraît déroulée, c'est-à-dire à partir d'un certain âge (50 ans environ). En effet, le passage de la sonde dans l'aorte descendante est moins difficile par la voie droite que par la voie gauche dès que la crosse aortique se surélève et s'allonge.

## Applications, résultats et critique de la méthode

En total, 196 applications de l'exploration ont été faites : gerbe aortique et vaisseaux du cou 26, aorte 57, digestives 64, sélectives rénales 48 et coronaire une. Pour certains patients la gerbe et l'aorte étaient explorées pendant le même examen.



F g 4 Retrograde ax lla re pour inject on de la n esen er q e nfer eure chez un pat ent atte nt de rectocol te hemo rag que



F g 5 Retrograde ax lla re pour nject on de l artere hepat que l a sonde est au-dela de l artere gastroduodenale (Étude du fo e d un s jet ethyl que )

*Inconvenients* La ponction axillaire est plus longue que celle de l artere femorale Le plexus brachial est une gene certaine Les echecs de cathetérisme sont plus frequents par cette voie mais il faut considerer que nous n avons plus de contre indication du fait de l etat arteriel partant nous avons beaucoup de patients qui ne pouvant subir un catheterisme femoral nous sont adresses

Sur 500 catheterismes arteriels nous avons fait 210 par voies axillaires Sur 28 echecs la ponction etait impossible (5), on ne passait pas (10) — la sous claviere (9) et le tronc arteriel brachiocephalique (1) — et la sonde ne pouvait pas tourner dans la crosse pour aller dans la descendante (13)

Pour ce dernier lot l examen est nul s il s agit de faire une selective Il est realisable pour une gerbe pour les vaisseaux du cou pour une aorte simple et on injecte alors dans la crosse Pour les aortographies on peut donc considerer les echecs a 15 ce qui fait 7 % C est encore beaucoup par rapport a la voie femorale Depuis que nous faisons des voies axillaires droites le passage dans la



Fig. 6. Rétrograde axillaire pour injection de l'artère hépatique et gastroduodénale. Il existe un diaphragme sur l'hépatique et une sténose de la gastroduodénale. La gastroépiploïque injecte l'artère splénique. (Sujet suspect d'atteinte pancréatique.)

crosse, quand elle est déroulée, se fait de façon plus facile. Une seule fois pour cette voie nous n'avons pas pu franchir la crosse aortique.

Roy sur 475 examens avait 46 échecs, à peu près 10 %. Nous pensons que notre proportion d'échecs diminuera avec le nombre d'explorations.

*Avantages.* "Il y a moins de manchots que de cul de jatte", ce qui prouve que les artères des membres supérieurs sont moins souvent altérées par l'athérome. Corollaire de la proposition sus jacente, le passage est presque toujours possible par l'axillaire, alors que les fémorales ne battent plus. Autre corollaire de la proposition première est que le risque est moindre : artères moins altérées et la revascularisation du membre supérieur est moins précaire en cas de thrombose.

Il s'agit pour notre part d'une méthode ambulatoire. Le patient peut rentrer chez lui 2 à 3 heures après l'examen. Il peut contrôler lui même, de la main opposée, son aisselle.

L'avantage le plus déterminant est dû à la facilité beaucoup plus grande des sélectives digestives (Boijsen 1966).

Du fait du trajet des artères et de leur inclinaison sur l'aorte, le cathétérisme descendant va dans le bon sens, il n'y a pas à faire de crochetage de l'ostium

comme dans le catheterisme ascendant crochetage qui interdit presque toujours de penetrer dans l artere au dela du premier centimetre on voit sur les radiographies combien la courbe du catheter dans la penetration est naturelle non forcee Ceci est valable non seulement pour les arteres abdominales mais pour les arteres pelviennes et celles du membre inferieur

*Incidents* Nous avons eu sept incidents Trois incidents etaient des traumatismes nerveux une dysesthesie des doigts definitive un trouble combine, moteur et sensitif de la pince pouce index mais partiel une paralysie du median par defaut de surveillance l hematome s est constitué dans les jours qui ont suivi l examen chez un sujet au psychisme a ce point fruste que c est a l occasion d une brulure grave de la main que l on a decouvert la paralysie et sa cause un mois apres la ponction cet accident n est pas entierement imputable a la methode Nous avons eu deux hématomes sans gravite Deux fois nous avons fait une dissection de la sous-claviere, le guide cheminant dans la paroi arterielle aucune manifestation n a suivi cette dissection et l examen a pu etre mene a bien

Il est interessant a noter que nous n avons jamais eu de thrombose le seul geste chirurgical que nous avons provoque est une decouverte sous anesthésie locale de l artere qui s est remise a battre apres infiltration de Syncaine

Roy (1965) fait etat sur 475 examens de 4 cas de traumatismes nerveux, dont les signes etaient presents un an apres et 11 cas de traumatismes arteriels — huit de disparition du pouls et trois qui necessitaient une thrombectomie Les autres se sont ameliores 7 cas d hematomes et une fois drainage chirurgical

Staal et coll (1966) sur 21 examens par voie axillaire fait etat de 7 lesions nerveuses deux durables Dubrick et coll (1967) sur 305 par voie axillaire avait deux types d accidents nerveux — l un benin engourdissement dans le territoire du cubital et l autre plus grave du au saignement dans la gaine neuromusculaire comprimant les branches du plexus brachial

Newton (1963) sur 160 cas n a pas eu d accident et Boijsen (1966) sur 70 examens par voie axillaire a eu un cas de thrombose axillaire

## Conclusion

Nous ne ferons que citer les *methodes indirectes d opacification arterielle par voie intra veineuse* (Cusmano & Gallaguer 1963 Steinberg et coll 1959, Viallet et coll 1959) Cette technique est reservee aux nourrissons et aux impossibilites arterielles

Les *techniques de ponction directe des gros vaisseaux* aorte (Dos Santos et coll 1931 Lemmon et coll 1959 Wickbom 1952) et sous-claviere (Morris

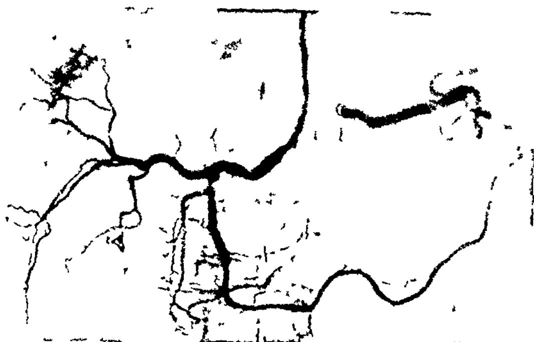


*Fig 6 Retrograde axillaire pour injection de l'artere hepatique et gastroduodenale Il existe un diaphragme sur l'hepatique et une stenose de la gastroduodenale La gastroepiploque injecte l'artere splenique* (Sujet suspect d'atteinte pancreatique )

crosse, quand elle est deroulee se fait de façon plus facile Une seule fois pour cette voie nous n'avons pas pu franchir la crosse aortique

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L'avantage le plus determinant est dû a la facilite beaucoup plus grande des selectives digestives (BOIJSEN 1966)

Du fait du trajet des arteres et de leur inclinaison sur l'aorte le catheterisme descendant va dans le bon sens il n'y a pas a faire de crochetage de l'ostium

**Tableau**

*Les accidents des differentes auteurs ayant publié la methode*

| Auteurs | Roy | Staal | Dubrick | Newton | Boijsen | Huguet |
|---|---|---|---|---|---|---|
| Cas | 475 | 21 | 305 | 160 | 70 | 210 |
| Échecs | 46 | — | — | — | — | 28 |
| Lesion arterielle | 3 | — | — | — | 1 | — |
| *Lésion nerveuse* | 4 | 2 | + | — | — | 3 |

Nous ne tenons compte que des lesions permanentes ou ayant nécessité une correction chirurgicale
Dubrick parle d accidents nerveux mais ne donne pas de chiffre

femorales aggrave le risque, pour les anevrysmes ou thromboses de l aorte abdominale, et enfin, l indication est preferable lorsqu il s agit d un malade que l on ne peut pas hospitaliser

Le *catheterisme arteriel par voie axillaire* est plus difficile mais il permet des investigations qui ne pourraient être faites autrement, il autorise des injections hyperelectives (Boijsen) Il faut connaître les risques nerveux encourus mais ceux ci doivent pouvoir être evites

## RÉSUMÉ

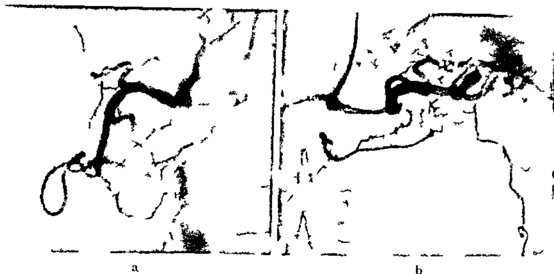
Les auteurs argumentent l interet de la voie axillaire pour introduire un catheter susceptible de faire des arteriographies de l aorte ou de ses branches La voie axillaire est plus difficile elle peut entrainer des blessures du plexus brachial avec sequelles definitives mais elle autorise des examens chez des patients dont les arteres femorales ne battent plus et permet des artériographies hyperelectives des arteres digestives

## SUMMARY

The value of catheterization via the axillary artery for angiography of the aorta and its branches is discussed Though approach via the axillary artery is comparatively difficult and can lead to injury of the brachial plexus with consequent sequlae the method may be recommended in the examination of patients having non pulsating femoral arteries and it also permits highly selective angiography of the digestive arteries

## ZUSAMMENFASSUNG

Der Wert der [illegible]
und deren Aste
relativ schwierige
[illegible] brachialis mit den entsprechenden







F 7 R tro a le ax ll re pour l etude des va sseaux pa creat ques s lect e de l artere l pat q e ncidence de 3/4 b) et c) Opac f cat o de l axe splenorenal retrograde ax lla re po r v s al ser la veine porte artere d corps et de la q e e d pancreas

1959) nous paraissent plus perilleuses que les techniques actuelles elles ont eu un grand merite avant l innovation de Seldinger

*Technique de contre courant a distance* (Castellanos & Pereiras 1950 Marshall & Linc 1963 Baird et coll 1965 Ecoiffier et coll 1964 Thierry et coll 1966) Elles sont faciles a realiser presentant un minimum de risques Elles peuvent etre employees pour l exploration des vaisseaux du cou et de la gerbe

*Le catheterisme femoral* (Lilifquist & Hellstrom 1965) Il est plus facile on doit lui preferer la voie axillaire pour toute arteriographie qui se veut tres selective (Cecille et coll 1965 Caron 1965 Klaus & Bron 1966) a sple nique a hepatique et gastro duodenale mesenterique inferieure (ne connait pas d echec par voie haute) les arteres honteuses lorsque l etat des arteres

THIERRY A., EYSSETTE, BIGAY et coll. Artériographie vertébrale par voie humérale rétrograde. J. Radiol. 47 (1966), 564.

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Folgen führen kann wird diese Methode für die Untersuchung solcher Patienten empfohlen deren Femoralarterien nicht pulsieren Diese Methode ermöglicht ausserdem eine hyper selektive Angiographie der Arterien des Verdauungstraktes

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR OVE MATTSSON), ERSTA SJUKHUS, STOCKHOLM, SWEDEN

# SIMPLIFIED SENSITOMETRY

by

OVE MATTSSON

It is important in the selection of radiographic materials, screen-film combinations and processing techniques to have available the characteristic curves, describing the relation exposure to density and providing all the information required Such curves are obtained by plotting the densities recorded against the common logarithm of exposures, the latter being the product of radiographic intensity and exposure time

A simple practical test for a comparison of two radiographic materials may be made by exposing both materials in an equivalent manner, stepwise increasing the exposure by employing a step wedge or some other means The comparison of densities may be made with the naked eye or the values may be read on a densitometer Only an approximate evaluation can be made in this way

When step wedges are used, the densities can be plotted versus step thickness. Step wedges suitable for radiography have been described e g by CORNEY & SEEMAN (1947) and SEEMAN & ROTH (1960) The latter described in 1962 a phantom for industrial radiography

Mistakes can be made in the comparison of films with a limited range of densities, if the films differ in contrast the characteristic curves intersect and the result may appear confusing when comparing the densities at different levels A material may give a better dose response at one level compared to another A series of representative steps over the whole range is necessary

Submitted for publication 5 June 1969



Fig 1 A sector wheel (with a common ratio of 2)

The problem of evaluating photographic qualities often arise in a roentgen department New deliveries of film or processing material, improved screens etc demand accurate quality control Sensitometry is too complicated to be carried out in an ordinary roentgen department since it may be difficult to achieve the required accuracy in exposures and obtain an extensive range of exposures According to HERCOCK (1963) an exposure range of at least 100 1 is required for testing roentgen materials but a range of 1 000 1 is preferable for comparative testing of materials that differ considerably in speed A suitable ratio is $\sqrt{2}$ or 2 For extreme values a change of intensity may be necessary, still complicating the procedure A sector wheel made of lead may facilitate the exposure, but stroboscopic effects caused by the intensity variation of the radiation from the alternating current may be disturbing A sector wheel with a common ratio of 2 is shown in Fig 1 The 'intermittence effect' may also influence the result – a phenomenon that appears when an exposure time is divided into many small periods — the total effect is lower than expected from the mathematical sum The reciprocity law failures may disturb the results in the range of exposures from some milliseconds to several seconds These failures have a certain practical importance in radiology (FRANTZELL 1950)

A simple technique for roentgen sensitometry with ordinary equipment of a roentgen department would obviously be of great value

Using a sequence of only three exposures in combination with a simple step wedge, all the levels of density required for a useful correlation of densities to exposures can be produced There is no critical limit to the dimensions of the step wedge The author has used plates of acrylate 10 mm in thickness and the number of steps has been varied from 10 to 15

With a fixed exposure setting providing a good exactness, exposure relations of 1 2 4 may be obtained by a repetition of single exposures in the required number, uncovering the film stepwise between the exposures

Three exposures give three density values for each density level, each group forms an incomplete portion of a density curve A complete series of recorded values is shown in Fig 2 If the wedge steps are not very different superimposition of the curves of various steps can easily be made, translucent paper will assist registration The result will be a characteristic curve with a great number of recorded values

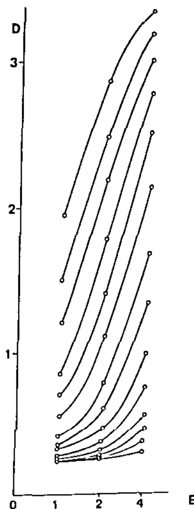



Fig 2 A complete series of recorded values from a test Each step is represented by an incomplete density curve

The curve may also be constructed in a more exact way The series of incomplete curves *represent the correlation exposure to density* in each step, the sequence of exposure values is logarithmic (1 — 2 — 4) From these curves the interval horizontally along the X-axis at each level can be estimated — the effective difference in intensity from step to step It is then possible to build up a complete curve with all density values plotted against the relative exposure intensities calculated (Fig 3a) The curve refers to a standard roentgen film exposed with screens and processed in a slow developing machine, a curve representing a roentgen film for industrial purpose exposed with screens is shown in Fig 3b The fact that most roentgen films possess high contrast means steep gradation, a long straight part of the curve *will facilitate the building of its final* form The limited range of exposure eliminates the risk of reciprocity law failures and the type of exposure means practically no risk of an intermittence effect

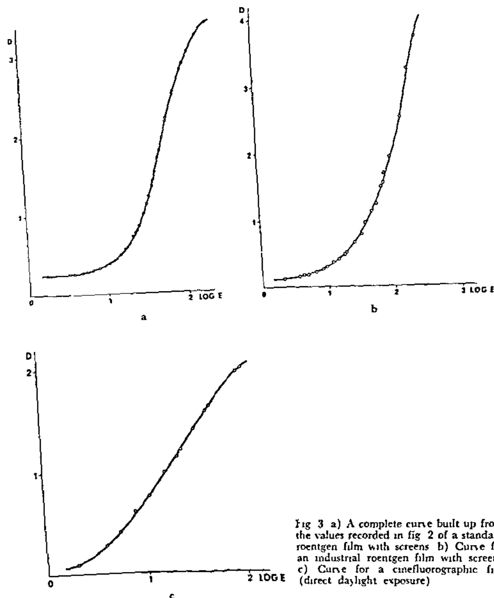



Fig 3 a) A complete curve built up from the values recorded in fig 2 of a standard roentgen film with screens b) Curve for an industrial roentgen film with screens c) Curve for a cinefluorographic film (direct daylight exposure)

From a practical viewpoint the method is realistic as unfiltered radiation never exists in radiography, the higher densities representing areas with low tissue filtration and the low density areas recordings of the highly absorbing parts of the

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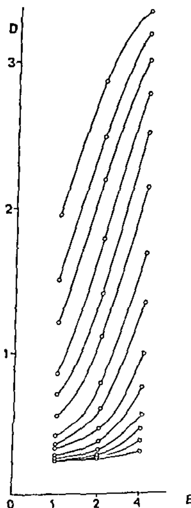



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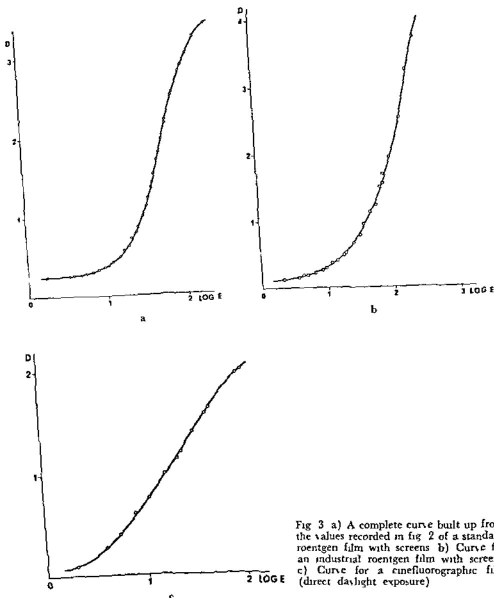



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object The true recording of contrast is obtained for each step of absorbtion level The final curve produces complete information on the practical qualities of the radiographic material tested

The principle has also been utilized for testing cinefluorographic film This is exposed in an ordinary camera with a conventional shutter mechanism One, two and four exposures are given on different frames, the object being a screen with various steps in plain grey under uniform illumination A curve obtained in this way is shown in Fig 3c

## SUMMARY

*A method of simplified sensitometry of radiographic material is presented No special apparatus is required*

## ZUSAMMENFASSUNG

Eine Methode fur die vereinfachte Sensitometrie von Rontgenfilmen wird vorgelegt Keine Spezialapparatur ist erforderlich

## RÉSUMÉ

Presentation d une methode de sensitometrie simplifiee du materiel radiographique Elle ne necessite pas d appareil special

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ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF
DENMARK, FINLAND, NORWAY AND SWEDEN

Vol 10 | DIAGNOSIS | 1970
Fasc 4 | | July

# TRAUMATIC ARTERIAL SPASM

## An angiographic study in rabbits

by

JAN GOTHLIN and TORD OLIN

Catheterization of arteries and veins is nowadays a common procedure in roentgenology, cardiology, clinical physiology, nephrology and surgery The procedure is sometimes complicated by spasm with ischemia, and intimal lesions with ensuing thrombosis may follow Arterial spasm has earlier been a problem, mainly during war surgery, as described by KROH (1917), MAKINS (1919), VON KUTTNER & BARUCH (1920), GRIFFITHS (1940), COHEN (1941, 1944) and DE BAKEY & SIMEONE (1946) Penetrating injuries causing spasm under more ordinary conditions were described by FREEMAN (1949), and following trauma in general by KYLLONEN (1966) Arterial spasm in connection with puncture and catheterization has been reported by several authors, e g RADNER (1951), LINDBOM (1957), WICKBOM & BARTLEY (1957), ELFVIN (1960), SCHECHTER (1963), SHELDON (1964) and LEVIN et coll (1967) The same conditions after vascular surgery were demonstrated by GESENIUS (1950) Arterial spasm caused by venous puncture was considered by SUTTON (1952), NABSETH & JONES (1963) and GARROW & KUSHNICK (1965) Fractures as a cause of spasm

From the Laboratory of Experimental Roentgenology, the University Hospital, Lund Sweden This work was supported by grant No B69 23X 605-03 from the Swedish Medical Research Council Submitted for publication 16 May 1969

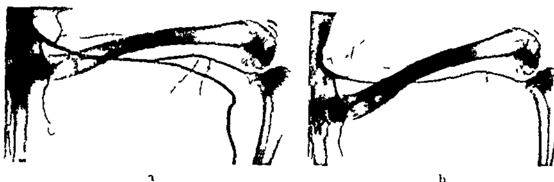



Fig 1 a) Normal angiogram of the left femoral artery b) Angiogram one hour after puncture of the femoral artery with a small cannula during fluoroscopy Spasm of the artery and its branches

were investigated by e g MONTGOMERY & IRELAND (1935), LERICHE (1939), GRIFFITHS (1940), COHEN (1941, 1944), CONSOLE (1948), KULOWSKI (1955) and WHOLEY & BOCHER (1967) Experimentally provoked spasm in animals has been studied in the arteries of the ear of the rabbit by GRANT (1929), in the arteries of the hindlimbs by BARNES & TRUETA (1942), in the femoral arteries of the rabbit and the cat by KINMONTH et coll (1949) and KINMONTH (1952) and in the femoral vessels of the dog by SCHWARTZ et coll (1961)

The effect of trauma applied either directly to the artery or to its adjacent nerves appears to have remained uninvestigated and no systematic study of the prevention is recorded in the literature These considerations prompted the present study

*Material and Methods* Thirty-five rabbits were examined under superficial general anesthesia with intravenous Mebumalnatrium (pentobarbitone sodium ACO, Sweden) except in one rabbit in which ether on an open mask was used A radiopaque polythene catheter (OPP 60, Portex, England outer diameter 1 15 mm, inner diameter 0 75 mm) was introduced into the right femoral artery under local anesthesia The tapered and suitably moulded tip of the catheter was placed in the left common iliac, the left subclavian and the right common carotid arteries, respectively, by the technique of ADAMS et coll (1965) Angiography was performed with Isopaque Cerebral (meglumine metrizoate, NFN, Nyco, Norway) injected at a constant rate with an infusion machine The film focus distance was 90 cm An incision was made in the left groin or the left axilla, so that the artery with accompanying nerves could be seen through the fasciae The common carotid artery, however, due to its deep position, was always dissected free and further angiography performed The artery and the accompanying nerves were then injured by forceps, or by

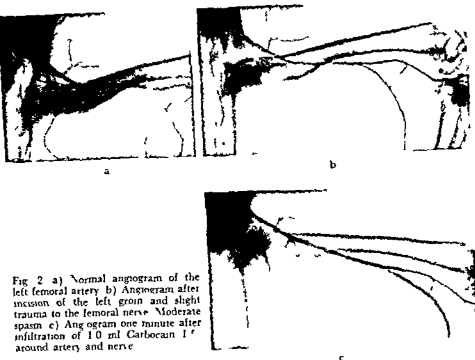



Fig 2 a) Normal angiogram of the left femoral artery b) Angiogram after incision of the left groin and slight trauma to the femoral nerve Moderate spasm c) Angiogram one minute after infiltration of 1 0 ml Carbocain 1% around artery and nerve

applying a thread around the artery and pulling it to and fro, or by puncturing the artery with a fine cannula. Repeat angiograms were then obtained Local anesthesia was sometimes infiltrated around the artery and the nerves before the trauma, but in other experiments it was applied following it The effect of vasoactive drugs administered through the catheter before and after the injury was also studied

## Results

Trauma of the *femoral artery and nerve* caused arterial spasm to a varying degree in nine experiments Puncture of the artery always produced severe contraction (Fig 1 a and b) whereas cautious free dissection inflicted only slight spasm (Fig 2 a, b and c) Non perforating trauma always resulted in less constriction than did puncture The spasm in advanced cases extended high up in the external iliac and far down in the popliteal artery, it arose soon after the trauma and developed fully in 1 to 2 minutes When no further procedures were taken, the contraction diminished to some degree although it was still





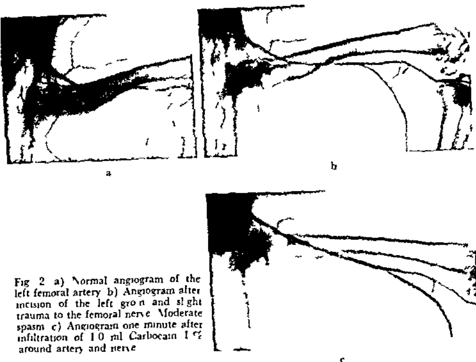



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Fig 3 a) Normal angiogram of left femoral artery b) Angiogram after pinching of the femoral nerve Slight spasm

evident for some hours The trauma in 16 experiments was applied only to the femoral nerve, the constriction developed was usually less marked than that after pure arterial stimulation (Fig 3 a and b) Cutting of the femoral nerve failed to change the calibre of the artery but segmental spasm in the saphenous artery sometimes appeared

*The brachial artery and nerve* were pinched or punctured *in 20 studies* The arrangement of the brachial plexus made it almost impossible to separate the artery and the nerves and even cautious free dissection resulted in marked spasm (Fig 4 a, b, c and d) in the brachial artery over some centimeters Puncture caused more spasm than pinching

Trauma of the *common carotid artery* in ten experiments produced no or only slight spasm (Fig 5 a and b) Even repeat puncture produced only a slight contraction Free dissection of the internal carotid artery, however, resulted in spasm

*Treatment of spasm in the brachial and femoral arteries* The effect of local anesthesia was studied on thirty occasions *If the anesthesia were correctly* applied (locally and proximally to the trauma) with Carbocain 1 % or Xylocain 1 %, no or only slight spasm appeared after the trauma When the local anesthetic agent contained epinephrine (5 $\mu$g/ml), moderate contraction appeared with the anesthetic in nine experiments Pure epinephrine (40 $\mu$g/ml) produced marked spasm (Fig 6 a and b) When local anesthesia was applied following trauma in ten studies, the already established spasm diminished considerably (Figs 2 b and c, 5 a and b, 7 a and b)

*α-receptor blocking agents* Three drugs have been tested Regitin (Phentol aminum INN, Ciba, Switzerland) was investigated in four experiments in which 0 25 to 0 5 *mg through the catheter relaxed the spasm in* one minute

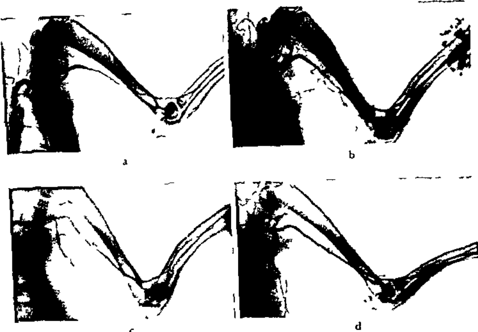



Fig 4 a) Angiogram after free dissection of the left brachial artery Marked spasm b) Angiogram six minutes after injection of 6 mg papaverine through the catheter Some relief of spasm c) Angiogram after free dissection of the left brachial artery Moderate spasm d) Angiogram one minute after injection through the catheter of 0 5 mg Regitin Relief of spasm

(Fig 4 a and b), although in one case slight contraction remained The dilating effect lasted more than 10 minutes Hydergin (Dihydroergotamin, Sandoz, Switzerland) in a dose of 0 03 mg in two experiments caused some diminution of the spasm Dibenyline (Phenoxybenzamine, Kline & French Lab , England) in a dose of 10 mg in two studies gave a good but incomplete relief

*β-receptor stimulating agents* Duvadilan (Isoxsuprinum INN, Ferrosan, Sweden) in doses of 0 05 to 0 6 mg was investigated in eleven experiments A dose of 0 125 mg was always sufficient to abolish spasm and in most cases the artery was wider after Duvadilan than in control angiography (Fig 8 a and b) The full effect was reached after 30 seconds and remained for at least 10 minutes, slight vasoconstriction returned in two experiments Arterial blood pressure, pulse pressure and heart rate were controlled in six studies and the deviation from normal was minimal after doses of 0 05 to 0 25 mg Vasculat Bamethanum NFN, Boehringer/Ingelheim, West Germany) was tested three times in doses of 2 5 to 10 mg with almost no effect on spasm




Fig. 5. a) Angiogram of the right common carotid artery after pulling the artery to and fro ten times with a thread. Almost no spasm. b) Angiogram five minutes after local application of 0.8 ml Carbocain 1 %. Moderate dilatation of the artery and no spasm.

*β-receptor blocking agents.* Inderal (Propranololum INN, ICI, England) was studied in three experiments in doses of 0.5 to 3.0 mg through the catheter or infiltrated around the vessel. No effect on spasm was evident.

*Ganglion blocking agents.* Arfonad (Trimetaphanum INN, Roche, Switzerland) was investigated in 12 experiments with control of arterial blood pressure, the doses varying widely due to tachyphylaxis. The drug was given intra-arterially or intravenously. When the arterial blood pressure was around 40 mm Hg angiography was followed by films during the return of the blood pressure to normal. In no case was there any effect on spasm. Arfonad infusion during the trauma *failed to prevent spasm*. *Papaverine* (*Papaverinum NFN*, ACO, Sweden) was tested seven times in doses of 0.25 to 6.0 mg. It more or less abolished spasm (Fig. 4 a and b), the full effect remaining for about five minutes. In two experiments papaverine in large doses before trauma resulted

a b

Fig. 6. a) Normal angiogram of the left femoral artery. b) Angiogram after local application of 0.08 mg epinephrine in 2.0 ml saline. Marked spasm.




Fig. 7. a) Angiogram of the left femoral artery after direct trauma to the artery. Moderate spasm. b) Angiogram one minute after direct application of Carbocain 1 %. Good but not complete relief of spasm.




Fig. 8. a) Angiogram of the left femoral artery after slight trauma to the femoral nerve. Slight spasm. b) Angiogram one minute after injection of 0.125 mg Duvadilan through the catheter. The femoral artery is much wider than in the control.

in only slight spasm after the injury. Eledoisin (Sandoz, Switzerland) has been investigated three times in a dose of 0.0035 mg; only slight effect was produced. Narcosis with ether on an open mask at different depths of anesthesia was tried without effect to relieve spasm. Rheomacrodex given through the catheter in a dose of 10 ml affected vasoconstriction only slightly.

*Treatment of spasm of the carotid artery.* This has been undertaken on nine occasions. Spasm of the common carotid artery, which was usually slight, was relieved by infiltration with local anesthesia. Dibenyline and Regitin hardly affected the spasm. Duvadilan intraarterially had some effect although this was not so obvious as in other vascular areas. Inderal had no effect at all. Spasm of the internal carotid artery, which is a small vessel in the rabbit, could be relieved only by local anesthesia.

## Discussion

Vasomotion has been extensively studied by many physiologists (see for example Handbook of Physiology, Circulation). The reactions of blood vessels to such stimuli as ion environment, vaso-active drugs and electrical stimulation have been closely investigated. Less thorough studies of more unspecific stimuli, such as trauma to arteries and nerves, have been performed. Both clinically and experimentally it has been demonstrated that trauma may cause spasm, but the mechanism is not clear. Direct mechanical stimulation of the vessel wall may produce spasm and KINMONTH (1952) ruled out nervous stimuli as the cause

TODD (1913) and TELFORD & STOPFORD (1930) pointed out that compression of the brachial plexus may produce the vascular symptoms in the syndrome of cervical rib, whereas LEWIS & PICKERING (1934) considered the vessel changes in such cases to be purely of a mechanical nature KULOWSKI (1955) successfully treated one case of spasm of the brachial artery after trauma by injection of local anesthesia in the median nerve SCHWARTZ et coll (1961) found in dogs that spasm provoked by trauma may vanish after injection of local anesthesia in the sheath of the supplying nerve Furthermore it has been demonstrated by WARREN et coll (1942), DE JONG (1961) and BERGSTRAND (1965) that vasodilation of the arteries of the arm is obtained after infiltration of local anesthesia in and around the brachial plexus MORTON & SCOTT (1931) and COHEN (1941) described spinal anesthesia as a method for relief of arterial spasm in the human leg For the same purpose sympathectomy was performed by FREEMAN (1949) in man, by BARNES & TRUETA (1942) in the rabbit, and by MARTIN et coll (1949) in the dog Periarterial dissection in order to abolish spasm has been described by LANGLEY (1923) in the cat, and by MONTGOMERY & IRELAND (1935), GRIFFITHS (1940) and COHEN (1941, 1944) in man

It is obvious that traumatic arterial spasm can be caused by different mechanisms Direct stimulation of the smooth muscles of the vessels or of the vasomotor nerves is one cause Another cause is indirect stimulation transmitted via the sensory nerves in the neighbourhood of the vessel The liability to spasm is influenced by psychogenic factors via the vasomotor center (MARINO et coll 1965)

The internal, external and common carotid arteries are surrounded by nerve fibres from the superior cervical ganglion The axillary and brachial arteries are supplied and surrounded by sympathetic fibres from the brachial plexus (DE JONG 1961) The innervation of the hind limb vessels of the cat has been investigated by MOORE & MOORE (1933), and of the dog by CLONINGER & GREEN (1955) and ZIMMERMAN (1966) CLONINGER & GREEN found by electrical stimulation of nerves that 89 1 % of the vasculature of the hind limb vessels was innervated by the sciatic nerve, 2 9 % by the femoral nerve and 2 1 % by fibres around the femoral artery

The marked spasm that trauma causes in the brachial artery may depend on the close relationship between the artery and the nerves KINMOTH et coll (1949) stated that in cats and rabbits traumatic spasm is easily provoked in the brachial and femoral arteries, with slight difficulty in the common and external iliac arteries and with great difficulty in the abdominal aorta and the common carotid artery WICKBOM & BARTLEY (1957) and LINDBOM (1957) produced spasm in human subjects on puncture or catheterization with angiography

especially in medium-sized arteries such as the brachial artery or the deep femoral artery. We found that trauma caused spasm more readily in the brachial and internal carotid arteries than in the femoral artery and that it was difficult to provoke this effect in the common carotid artery. The experiments thus confirm the findings of WICKBOM & BARTLEY (1957) and LINDBOM (1957) that the spasm liability diminishes with increasing diameter of the vessel This might to some extent depend upon the fact that the proportion of elastic tissue of the wall increases with the diameter of the vessel According to LINDBOM (1957) fibrosis of the medial layer of the arterial wall is common in the middle-aged and elderly Arteries so affected cannot contract and spasm is therefore uncommon in these types of patients; according to LINDGREN (1969) this indicates the importance of age The age factor was not investigated in the present work.

Trauma of the femoral nerve caused less spasm than direct arterial trauma and can be explained by the observation by CLONNINGER & GREEN (1955) that most of the innervation of the vessels of the hind limb is transmitted by the sciatic nerve The sensory innervation of the arteries has been investigated by e g MOORE & MOORE (1933) and MOORE & SINGLETON (1933) Spasm is common especially in young individuals in clinical work with puncture and catheterization It seems most often to be caused by stimulation of the inside of the vessel wall by the tip of the needle or the catheter or by the jet of contrast medium

The smooth musculature of the vessel wall contracts slowly with small amounts of energy, the contraction being maintained at a low level of energy consumption Relaxation occurs gradually as evident after death, when the arteries may stay constricted for a long time Spasm is also maintained in vivo for a long time if active therapy is withheld

The investigation indicates that to prevent or abolish spasm it is necessary to apply local anesthesia freely around the artery and the surrounding nerves and that it should also be infiltrated centrally to the puncture The spasm has a tendency to spread both centrally and peripherally *It is always better to apply anesthesia before trauma than after* The severe cases of spasm that arise in clinical angiography have appeared after local anesthesia limited to the skin The disadvantages of a large amount of anesthetic is, of course, that it may make arterial pulsation difficult to palpate, but this can be overcome by adding Hyalas (Hyaluronidase, Leo, Sweden), 40 I U to 10 ml of anesthetic, or by massaging the infiltrated area In earlier clinical descriptions of spasm in connection with puncture local anesthesia has not been mentioned

The liability to spasm is increased in tense and nervous individuals MARINO et coll (1965) demonstrated experimentally that psycho stress potentiated

vasoconstriction on injection of epinephrine or ergotamine Some kind of sedation before the catheterization is thus important

Established spasm has been treated by periarterial dissection, sympathetic block, sympathectomy, local anesthesia to the supplying nerve and various vasoactive drugs given locally or intraarterially Papaverine has been tried with varying results by GRIFFITHS (1940), FREEMAN (1949), MARTIN et coll (1949), RADNER (1951), KINMONTH (1952), SUTTON (1952) and SCHWARTZ et coll (1961) Infiltration of procaine has been stated to relieve arterial spasm by KINMONTH (1952), KULOWSKI (1955) and SCHWARTZ et coll (1961) Good results with Priscol have been reported by KINMONTH (1952) and WICKBOM & BARTLEY (1957)

Of the drugs tested by the present authors the $\beta$ receptor stimulating agent Duvadilan was the best It relieved spasm of the brachial and femoral arteries effectively in a low intraarterial dose that produced little effect on the general circulation Duvadilan gave complete relief of spasm after 30 seconds, the vessels usually being wider Slight spasm sometimes returned after more than ten minutes A good effect was obtained with the $\alpha$ receptor blocking agents Regitin and Dibenyline as occurred with papaverine, a good effect in high doses although its traditional role as a spasm relieving drug seems to be outdated The ganglion blocking agents had no effect on the calibre of the vessels, perhaps explained by the drop in blood pressure that occurs on their administration Eledoisin, Rheomacrodex and ether narcosis exerted only small positive effects

## Conclusions

Prevention of spasm at puncture and catheterization is important The patient should be calmed with sedation and a good local anesthetic given before the procedure If spasm appears one of the new local anesthetics should be applied, if necessary as conductance anesthesia, e g plexal anesthesia Failing relief, a vasodilating drug should be injected intraarterially, preferably Duvadilan, if this drug is not accessible, an $\alpha$ receptor blocking agent or papaverine should be tried

## SUMMARY

Arterial spasm caused by trauma to an artery or adjacent nerves has been studied experimentally in rabbits Severe spasm was easily provoked in the brachial artery, the femoral artery responded less and the common carotid artery was resistant The treatment of spasm is discussed

especially in medium-sized arteries such as the brachial artery or the deep femoral artery We found that trauma caused spasm more readily in the brachial and internal carotid arteries than in the femoral artery and that it was difficult to provoke this effect in the common carotid artery The experiments thus confirm the findings of WICKBOM & BARTLEY (1957) and LINDBOM (1957) that the spasm liability diminishes with increasing diameter of the vessel This might to some extent depend upon the fact that the proportion of elastic tissue of the wall increases with the diameter of the vessel According to LINDBOM (1957) fibrosis of the medial layer of the arterial wall is common in the middle-aged and elderly Arteries so affected cannot contract and spasm is therefore uncommon in these types of patients, according to LINDGREN (1969) this indicates the importance of age The age factor was not investigated in the present work

Trauma of the femoral nerve caused less spasm than direct arterial trauma and can be explained by the observation by CLONINGER & GREEN (1955) that most of the innervation of the vessels of the hind limb is transmitted by the sciatic nerve The sensory innervation of the arteries has been investigated by e g MOORE & MOORE (1933) and MOORE & SINGLETON (1933) Spasm is common especially in young individuals in clinical work with puncture and catheterization It seems most often to be caused by stimulation of the inside of the vessel wall by the tip of the needle or the catheter or by the jet of contrast medium

The smooth musculature of the vessel wall contracts slowly with small amounts of energy, the contraction being maintained at a low level of energy consumption Relaxation occurs gradually as evident after death, when the arteries may stay constricted for a long time Spasm is also maintained in vivo for a long time if active therapy is withheld

The investigation indicates that to prevent or abolish spasm it is necessary to apply local anesthesia freely around the artery and the surrounding nerves and that it should also be infiltrated centrally to the puncture The spasm has a tendency to spread both centrally and peripherally It is always better to apply anesthesia before trauma than after The severe cases of spasm that arise in clinical angiography have appeared after local anesthesia limited to the skin The disadvantages of a large amount of anesthetic is, of course, that it may make arterial pulsation difficult to palpate, but this can be overcome by adding Hyalas (Hyaluronidase, Leo, Sweden), 40 I U to 10 ml of anesthetic, or by massaging the infiltrated area In earlier clinical descriptions of spasm in connection with puncture local anesthesia has not been mentioned

The liability to spasm is increased in tense and nervous individuals MARINO et coll (1965) demonstrated experimentally that psycho-stress potentiated

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## ZUSAMMENFASSUNG

Experimente wurden an Kaninchen vorgenommen um die Entstehung von arteriellen Spasmen zu studieren die durch Trauma der naheliegenden Gefasse oder Nerven hervorgerufen wurden Schwerartige Spasmen konnten ohne Schwierigkeit in der Brachialarterie hervorgerufen werden Die *Femoralarterie reagierte weniger und die Carotisarterie blieb* unbeeinflusst Die Behandlungswege der Spasmen werden diskutiert

## RÉSUMÉ

Les auteurs ont etudies experimentalement sur des lapins le spasme arteriel cause par un traumatisme portant sur une artere ou sur les nerfs voisins On provoque aisement un *spasme grave sur l artere humerale l artere femorale repond moins et l artere carotide* primitive ne repond pas au traumatisme Les auteurs examinent le traitement du spasme

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# POSITION OF THE 'VENOUS ANGLE' IN THE MEDIAN SAGITTAL PLANE

## A new topometric method

by

FRANZ P PROBST

The deep veins of the brain, particularly the internal cerebral vein and its tributaries, can supply valuable information about adjacent cerebral structures. They are thus an important aid in the diagnosis of expanding intracranial lesions as well as in the investigation of malformations and other pathologic conditions of the brain substance

The so-called 'venous angle' has been given much attention in the literature. The term venous angle is not altogether correct, but it is used by some investigators to designate the angle formed between the striothalamic and internal cerebral veins. This angle may be distinguished more or less readily in lateral views, it appears in about 80 % of all carotid angiographies, and its apex marks the posterior superior limit of the interventricular foramen

The position of the internal cerebral vein may be assessed without difficulty in the a p projection. It is harder to localize the venous angle in the sagittal plane because consideration must be paid not only to physiologic range in relation to

Submitted for publication 1 April 1969

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media and posterior horn, these veins run in the medial wall of the lateral ventricle and enter the internal cerebral vein at slightly different angles

2 A lateral group including veins from the lateral wall of the cella media, these are located subependymally on the medial surface of the caudate nucleus, and when they do not empty into the striothalamic vein, run medially on the superior surface of the thalamus They then pass beneath the stria terminalis and the taenia choroidea, enter the velum interpositum, and finally reach the internal cerebral vein

Orientation of the venous angle by objective measurement requires that the apex of the angle lies in the foramen of Monro, it is also important to know whether a 'false venous angle' is present, in other words whether the striothalamic vein enters the internal cerebral vein behind the foramen

*False venous angles* All variations with 'medial' or 'lateral' vein stems opening into the anterior third of the internal cerebral vein may cause diagnostic difficulties They may erroneously suggest a displacement of the venous angle, with elevation or distortion of the internal cerebral vein if the true venous curve running through the foramen of Monro is not visible in the phlebogram Invisibility of the true angle may be due to aplasia, hypoplasia, or inadequate contrast filling The venous angle may in some cases be visible only for a brief moment, and may sometimes be seen only in one view in the early venous phase The true conditions may then be ascertained by studying each film in the sequence-set with a subtraction mask Not infrequently, identification of the [illegible]
made difficult by overlying superficial
or the vein of Labbe However, as th
these vessels more rapidly than through the deep veins views from the late venous
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(1956) and
[illegible] facilitate the recognition of false venous angles

*Orientation of the venous angle by objective measurement* All methods for localization of the venous angle in the sagittal plane by measurements are based upon its position being related to certain craniometric points These points should meet certain requirements They should lie in the median sagittal plane, be exact and always capable of definition, and be situated in regions having the least possible variability The foot points most commonly used for earlier coordinate systems were the tuberculum sellae, nasion or a point on the glabella, bregma, lambda, inion, opisthion, or basion Even points such as 'the lowest point in the sella turcica', 'the top of the dorsum sellae', and 'the point where the internal cerebral vein enters the straight sinus' have been used Structures with a lateral

cranial shape and size but also to the relatively high rate of anomalies in the anterior portion of the internal cerebral vein and its tributaries

Many attempts have been made to find a more exact method than visual assessment for determining the position of the venous angle in the sagittal plane The technique for orientation of the pineal body described by VASTINE & KINNEY (1927) has been used as a prototype in some of these investigations Other authors have tried various coordinate systems in which the lines of reference were determined by given craniometric points As with the pineal body, the multitude of methods suggested for measurement of the venous angle are indications that they are not wholly satisfactory

*Anatomy* Excellent descriptions of the deep-vein system of the brain have been published by, among others, JOHANSSON (1954), MOKROHISKY et coll (1956), RING (1959), and WOLF & HUANG (1964)

The striothalamic vein is usually the largest tributary to the internal cerebral vein It forms the continuation of the terminal vein which lies in the terminal groove between the thalamus and the caudate nucleus After being joined by an anterior and a posterior caudate vein, it curves medially around the anterior part of the thalamus in the direction of the foramen of Monro

The aperture between the lateral and third ventricles consists of a short, crescent-shaped canal, the foramen of Monro, across the upper margin of which the striothalamic vein together with the choroid plexus passes to join the vein of the septum pellucidum and the choroid vein to form the internal cerebral vein this courses backwards as a continuation of the curve with its convexity forwards produced by the striothalamic vein There is no break in the continuity of the curve, and thus, according to general opinion, the internal cerebral vein always arises in the foramen of Monro The vein of the septum pellucidum sometimes terminates occipital to the origin of the internal cerebral vein The latter vessel has a characteristic course, running backwards in the roof of the third ventricle and along the medial border of the thalamus Viewed laterally, it describes a sinus shaped curve with its convexity upwards It lies mainly in a parasagittal plane close to the midline The two internal cerebral veins commonly unite above the suprapineal recess to receive the basal veins and form the great vein of Galen, which follows the splenium of the corpus callosum and joins with the inferior sagittal sinus to continue as the straight sinus

A number of tributaries, most of them minute and not demonstrable at clinical angiography, empty into the internal cerebral vein Only a few of the larger stems are of interest, and according to WOLF & HUANG (1964) may be classified in two main groups

1 A medial group including veins from the roof and medial wall of the cella



Fig 2 Method of Lin et coll (1955)

planum sphenoidale, and the anterior vertical axis was drawn tangent to the inner table of the frontal bone The internal cerebral vein in normal cases lay in the third and fourth squares, counting from the front, and in the second row of squares, counting from the base line As both of these methods gave only approximate orientation they will not be discussed

MASPES & DONEGANI (1952) attempted to determine the normal variations of the venous angle with a rectangular coordinate system (Fig 1a) The base line N I *consisted* of a line joining the point on the anterior wall of the frontal sinus lying above the nasion and farthest rostrally (i e not a point on the nasion), and *the tip* of the inion The Y axis was drawn in NI/2 = O The distance O'-M (M = the venous angle) was placed in relation to O V and the distance O'-I in relation to N I (22 to 36 % and 52 to 60 %, respectively), a *rectangular zone of* dispersion 15 mm long and 14 7 mm high was obtained *In the light of what has* been stated regarding the suitability of *different craniometric* orientation points as a basis for a coordinate system the base line chosen by these investigators must be regarded as unsuitable, their results confirm this *opinion* The nearly square topogram permits diagonal variations of, *at the most*, 22 mm in the position of the angle A non elliptic topogram is unsuitable, *and cannot reflect* the normal range of variation correctly

MASPES & DONEGANI also described a goniometric system of measurement in which, however, the points for the angle *were unfavorably* located in regions of great variability The resulting topogram had an irregular, trapezoid form, and furthermore varied in shape and size from case to case

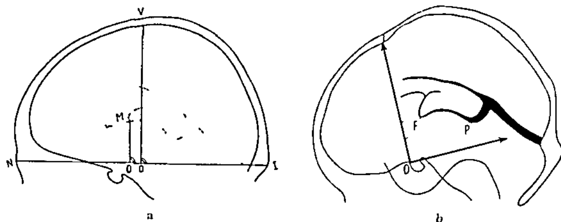



Fig. 1. a) Method of MASPES & DONEGANI (1952). b) Method of JOHANSSON (1954).

site, such as the roof of the orbit or the external auditory meatus, have also been employed.

BERGERHOFF's (1953) investigations have demonstrated that the cranium develops around the tuberculum sellae. The part of the skull situated in front of the tuberculum sellae and the bregma is considered to be subject to relatively little variation, while points in the parietal or occipital part lie in regions of greater variability. Judged by these criteria, the various craniometric points differ widely in suitability. The site of the tuberculum sellae can nearly always be determined and is considered to be the point that varies least; it lies close to the venous angle. This point thus seems to be the most suitable one to use as the foot point for the base line of the coordinate system. If a system with rectangular coordinates is used, one more craniometric point, the nasion for instance, will be sufficient to give the base line a direction. If a coordinate system whose lines of reference are determined by four craniometric points is selected, it will of course not be rectangular but will vary from case to case, and this reduces the possibility of defining the normal range of variation for the venous angle. The physiologic variation of the craniometric measurement points affects to a greater or less degree the position of the venous angles in relation to the origin of the system.

*Earlier methods.* The first authors to attempt systematic localization of the venous angle were CURRY & CULBRETH (1951), who measured the distance from the 'anterior convexity' of the striothalamic vein to the extremity of the posterior clinoid process and found that it ranged from 3.5 to 4 cm.

UMBACH (1952) used a rectangular coordinate system consisting of a squared net with 3 cm × 3 cm meshes. The base line was placed parallel to and in the

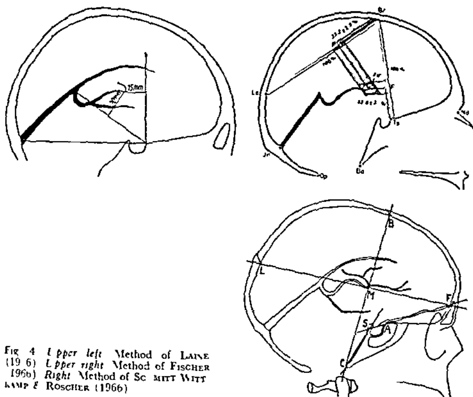



Fig 4 *Upper left* Method of LAINE (1956) *Upper right* Method of FISCHER (1966) *Right* Method of SCHMITT WITTKAMP & ROSCHER (1966)

direction it was 12 mm in 92 % of the cases and 18 mm for all cases, and in the basovertical direction 12 mm in 98 7 % and 14 mm in 100 % of the cases In 55 % of the authors 26 cases with space-occupying lesions (including 3 cases of hydrocephalus), the venous angle fell outside the narrower limiting range, but only 37 % exceeded the wider limits These investigators concluded that their method had only a restricted application The method takes into account the size and configuration of the skull by relating the two lines of reference with total length and height but its weaknesses are fairly obvious It is a coordinate system with varying angulation, since the angles at the O point (A) vary from case to case The venous angles are determined only in two major directions (which vary furthermore), and consequently the two resulting charts cannot be integrated into a topogram allowing localization of the individual venous angles with respect to distance and direction in relation to a calculated O point The latter measure is possible only in topograms based on an unvarying coordinate system

WOLF NEWMAN & SCHLESINGER (1955), using a template, worked out a

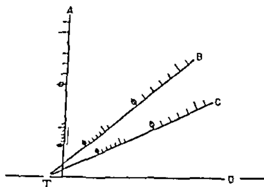



Fig 3 Method of Wolf, Newman & Schlesinger (1955) 'Constant ratio scale' A for determining position of venous angle

Johansson (1954) used a rectangular coordinate system (Fig 1b) with the origin in the tuberculum sellae (O) The distance from O to the endobregma formed the Y-axis, and the X-axis was drawn at right angles to this line, through the origin Johansson determined the coordinates for point Γ (the venous angle) in 200 normal angiograms, and found that 80 % of the observations lay within a circle with a diameter of 15 mm Calculated with ± 3 sigma, the outer limit for the normal variations formed a circle with a diameter of 22 mm Only 15 5 % of this author's patients with expanding cerebral lesions had values outside the 3-sigma limit *He concluded that displacement of the venous angle could be* demonstrated by his technique with certainty in relatively few cases He also considered that visual inspection by an experienced examiner was a better method for determining the shape and position of the venous angle than his measuring technique Johansson's results were carefully described and analyzed statistically, but nevertheless they must have been influenced considerably by the variability of the bregma Every variant of the bregma causes rotation of the coordinate system and distorts the distribution and natural variation range of the venous angle

Lin et coll (1955) and Mokrohisky et coll (1956) employed a measuring *technique similar to Vastine & Kinney's (1927) method for orientation of the pineal body (Fig 2) Their investigation was based on 100 'normal' cases and the* position of the venous angle could be established in 77 instances The base line (B) was drawn through the tuberculum sellae, its direction being determined by the nasion A perpendicular line, the Y axis, was drawn from this, through the convexity point along the venous angle (A) to the inner table of the vault The position of the venous angle in the anteroposterior direction was measured along a line passing through A, which had to be the longest fronto-occipital distance between the inner tables *(D) The two orientation charts presented were obtained* by diagramatically plotting D against D′ and C against C′ For each diagram the range of variation was limited empirically by parallel lines, in the anteroposterior

scales, B and C, will not be discussed, as these are outside the scope of this review

LAINE et coll (1956) worked out a triangular topogram based on 69 normal phlebograms. Their base line was drawn from the tuberculum sellae to the lower margin of the sulcus for the transverse sinus The Y axis was drawn perpendicular to this line, in the tuberculum sellae, and the X axis ran between the tuberculum and the junction of the vena magna with the inferior sagittal sinus (Fig 4) Thus, the direction of the X axis was determined by a point which probably is the most variable of all so-called 'fixed points' A triangular topogram constructed from such varying coordinates obviously cannot reproduce the physiologic variations of an anatomic structure This method nevertheless became known and was relatively well accepted

RING (1959) tested LAINE's method and found that only 55 % of the venous angles lay in the triangular topogram He tried to improve the technique by eliminating the ampulla Galeni as a point of direction for the X-axis, using instead the point where the posterior pericallosal vein joins the vena magna This point has a more constant position, but on the other hand it is not always visible (not seen in about 50 % of cases) He worked out an elliptic topogram, in which 75 % of his venous angles could be included The size of the ellipse was given as 6 8 mm, but the direction of the long axis was not mentioned This ellipse is, of course, too small to include the normal range of the venous angle

BRANDT (1959), in an extensive goniometric investigation, measured a large number of angles from the tuberculum sellae, bregma and ampulla Galeni to the venous angle He found no statistical covariation between these points He also measured the angles to the tuberculum sellae and a base line from the tuberculum tangent to the orbital roof, the distance to the tuberculum was measured as well The positions of the venous angles were placed in an ellipse For 90 % of the cases the ellipse had a long axis of 23 mm and a short axis of 19 mm The magnification factor was 1 27, and reduced to absolute values the measurements of the ellipse were 18/14 8 mm This method does not take the size and configuration of the skull into consideration, and the ellipse is far too large to be practically usable

FISCHER, in 1966 presented another technique for orientation of the venous angle By means of a system with coordinates of varying lengths, and with varying angulation, Br—Ts and Br—La, he determined the range of variation perpendicular to, and along these lines (Fig 4), and obtained the following results If the line between the tuberculum sellae and endobregma is divided from below in the ratio of 32 58 % ± 3 07 %, and the line between the endobregma and endolambda is divided from above in the ratio of 33 32 % ± 2 5 % and if perpendicular lines are drawn at these points, a parallelogram is obtained The venous angle lies as a rule at the point of intersection of the central lines The natural variation range

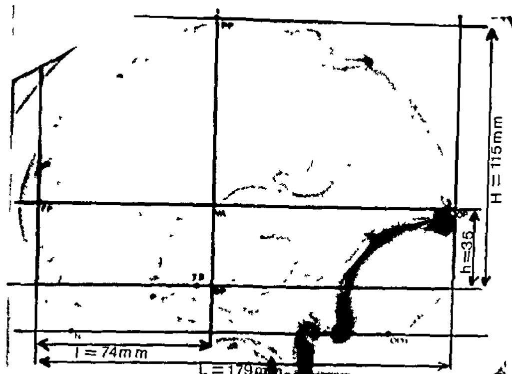



Fig 5 Author's method V A — venous angle, TS — tuberculum sellae BP foot point

proportionality system described as 'constant ratio scales' for determining the expected positions of the points AL (venous angle), MP and LP (Fig 3) Constant ratio scale A was drawn perpendicular to the base line (tuberculum sellae to lower margin of the sulcus for the transverse sinus), with the foot point located 13 mm occipital to the tuberculum sellae The method was an attempt to establish a constant ratio between the variation range of the venous angle and the inner table of the calvarium in relation to the tuberculum sellae along the vertical line The range for the venous angle along this line was given as 18 mm, the range in the frontal direction was not considered important, and no figures were mentioned One of the venous angles investigated lay 2 5 mm behind the vertical line Venous angles situated more than 2 5 mm behind constant ratio scale A were interpreted as displaced The method is in principle a modification of the technique used by LIN et coll, and may be said to correspond to their orientation chart, which shows the variations in the basovertical direction The main difference is that the coordinates are rectangular and that the method does not take into consideration the variations in the fronto-occipital direction Twenty-four normal phlebograms were used as a basis for the method The techniques recommended for determining points MP and LP by using two other constant ratio

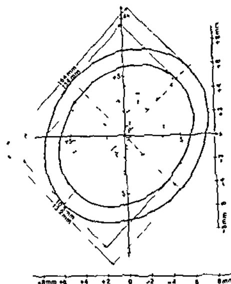


Fig 7 Prediction areas of venous angles calculated for 95 % and 99 % probability, measuring 110 $mm^2$ and 169 $mm^2$ respectively

by craniometric points such as the basion, bregma, lambda, and a point of intersection between the inner cortex of the frontal bone and a line from the tuberculum sellae making a tangent with the orbital roof According to these authors, the venous angle usually lies at the intersecting point of the coordinates, and on the coordinates The deviations from these lines decrease basovertically and fronto-occipitally, since the distribution in relation to each line follows the Gaussian distribution curve The measurements were made on the principle that the distance to line L—F was determined parallel to line C—B, and vice versa (The geometrical figure formed by coordinates and subcoordinates was a parallelogram The distance between a venous angle and the point O was the long or the short diagonal, depending on whether it lay in the acute angled or the obtuse-angled segment of the coordinate system ) Each venous angle was then plotted in a system with rectangular coordinates, and the deviation values thus obtained were compiled into ellipses *measuring* 14/11 4 mm when calculated with $P = 0\ 05$, and 17 4/11 4 mm when calculated *with* $P = 0\ 01$ (magnification factor 1 3) The center of the ellipses lay 0 7 mm in front of the vertical coordinate and 0 4 mm above the horizontal coordinate The long axis of the ellipse cut the abscissa at an angle of 20°, in other words, the ellipses sloped forward at the base The area of the ellipse calculated *with* $P = 0\ 01$ was 156 $mm^2$

This technique seems better than all the earlier methods The present author has however tried it in 30 consecutive carotid angiographies in which the bregma and lambda were visible, and found that the distances from the venous angle to

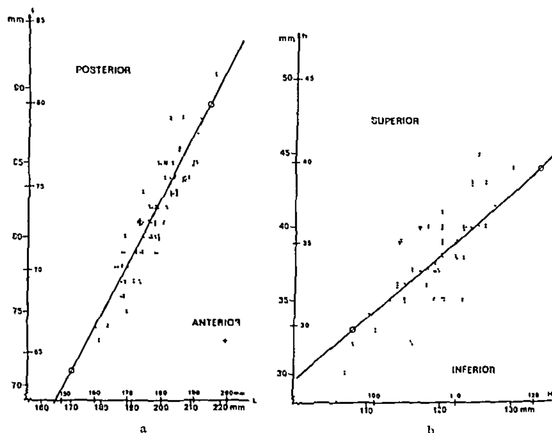



Fig 6 Regression lines Inner scales absolute values outer scales magnification 1 11 a) Fronto occipital range of venous angles in relation to inner length of skulls b) Basovertical range of venous angles in relation to height of skulls

(the 2-sigma value) will then be represented by an ellipsoid (as large as possible sketched empirically into the parallelogram For geometrical reasons, the long axis of the ellipse can then never coincide with the long axis of the parallelogram It may thus be said that the size, shape and direction of the ellipse varies from case to case, depending on the angle La—Br—Ts, and variations in the corresponding lines

Schmitt-Wittkamp (1966), who also tried Fischer's method, found that the mean area of the ellipse, when calculated with P = 0 01, was 2 7 cm² As Fischer's method is based on proportionality measurements, the range of variation will vary with the dimensions of the skull

The latest contribution to the problem of localizing the venous angle was published by Schmitt-Wittkamp & Roscher in 1966 (Fig 4), who described an investigation based on 122 cases These authors used a coordinate system with varying angulation, and the directions of the coordinates were determined

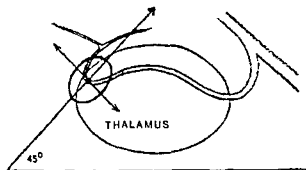



Fig 8 The ellipses slope toward the base line angle of inclination 45°

theless remarkably low in this material and the explanation probably lies in the program, with rapid film sequences, as well as in the systematical analysis of the views from the venous phase with the subtraction technique

*Technique* The system was regarded as lying in the median sagittal plane (Fig 5)

The line Na—OPH gives the direction for all lines in the system (the *direction line*)

The system is constructed on the *base line*, which is drawn parallel to the direction line, through the tuberculum sellae (TS)

The *venous angle horizontal* is drawn parallel to the former lines, through the venous angle (VA)

The *parietal line* is drawn parallel to the others, and tangentially to the inner table of the parietal bone

The following lines are drawn perpendicular to the base line

The *frontal line* which will be tangential to the inner table of the frontal bone, the *venous angle vertical* through VA, and the *occipital line*, which is made tangential to the inner table of the occipital bone

The following distances were measured in millimeters and half millimeters FP—VA = frontal distance (1), FP—OP = total length (L), BP—VA = basal distance (h) and BP—PP = total height (H)

Two integrable charts were constructed from the length and height measurements by plotting (1) against (L) and (h) against (H) The range of the venous angles in a fronto-occipital direction in relation to skull length (chart I) and the range in vertical direction in relation to skull height (chart II) are shown in Fig 6 The regression line in each chart is identical with the y- and x axes, respectively in Fig 7, in which the charts are integrated Each venous angle was plotted in relation to the coordinates y and x The range of variation (prediction area) is limited by ellipses obtained by multivariate analysis These were calcu-

the origin varied from 0 to 13 mm The average distance was 5 66 *mm, and in* 9 cases the distance was greater than 7 5 mm The original ellipse measurements (calculated with P = 0 01), when recalculated to allow for a magnification of 1 11, were 15 mm for the long axis and 9 8 mm for the short axis Consequently, all distances exceeding 7 5 mm lay outside the ellipse, some of the other venous angles whose distances to the origin were greater than 4 9 mm also, of necessity, fell outside the ellipse

The reason for this unsatisfactory result is to be sought in the previously mentioned wide individual variations in the bregma and lambda (BERGERHOFF), as well as in the inherent error of method If values obtained in a coordinate system with varying angulation are transferred to a system with rectangular coordinates the relation to the origin will be altered for every venous angle, both as regards *distance and direction, this will cause* a radical change in the venous angle distribution, with consequences both for the dimensions and the angle of inclination of the ellipses

*If* this geometrical error could be eliminated or reduced (which is not possible however, since 122 angle-varying coordinate systems cannot be integrated), the *ellipses would probably be larger than mentioned, there would however still be no* possibility of giving the ellipse an exact direction Another unfavorable factor in *this method is that the fixed points used are surprisingly often difficult to* distinguish clearly

## Measurement method

*Material* This was composed of 250 consecutive carotid angiographies from adults judged to be normal The indications for the angiographic examinations had varied (epilepsy, vascular accident, and subdural hematoma or tumor)

At least two projections, half-axial and lateral, from each investigation were examined, *and the views from the venous phase were studied with the subtraction* technique The criteria for selection were that the subependymal veins of the lateral ventricle should be sufficiently well filled with contrast medium to permit assessment of the shape and size of the ventricle, with the exception of the temporal horn, and that the venous angle and internal cerebral vein *should be distinctly* visible Angiographies not fulfilling these conditions were discarded Among the 250 cases, there were *34 (13 6 %) with venous angles differing* from the normal appearance and in sites typical of false venous angles These cases were not used in the *orientation measurements,* 216 angiographies (86 4 %) were thus available for the study of the normal range False venous angles were present on one *side only* in 5 cases and the true position of the venous angle could be seen in the phlebogram from the other side The frequency of false venous angles is never

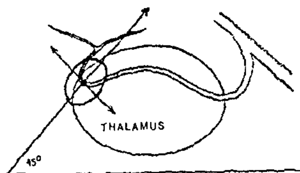



Fig 8 The ellipses slope toward the base line angle of inclination 45°

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[illegible] the length and height measurements by plotting (l) against (L) and (h) against (H) The range of the venous angles in a fronto occipital direction in relation to skull length (chart I) and the range in vertical direction in relation to skull height (chart II) are shown in Fig 6 The regression line in each chart is identical with the y- and x axes, respectively in Fig 7, in which the charts are integrated Each venous angle was plotted in relation to the coordinates y and x The range of variation (prediction area) is limited by ellipses obtained by multivariate analysis These were calcu-

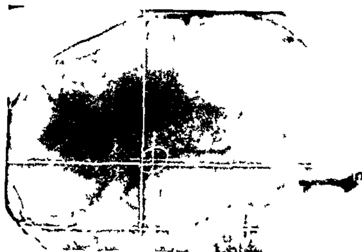


Fig 9 Venous angle with marked anterior location due to dolichocephaly, skull long posteriorly, the venous angle lies within the 99 % prediction area Cross in center of ellipse denotes the *calculated position*

lated with 99 % probability ($P = 0.01$) and 95 % probability ($P = 0.05$), as shown in the statistical calculations The large ellipse measures 16 4 mm/13 2 mm and the small ellipse 13 4 mm/10 5 mm, and their areas are 169 mm² (99 %) and 110 mm² (95 %), respectively The axes of the ellipses cut X (identical with the venous angle horizontal) at an angle of 45° (the angle of inclination, see Fig 8) Owing to the slope of the ellipse, the maximum range of variation in both vertical and horizontal directions is ± 7 35 mm (99 %) and 5 95 mm (95 %) The maximum distance from the point 0 along the major axis is 8 2 mm and 6 7 mm, respectively, and along the minor axis 6 6 mm and 5 25 mm, respectively

## Discussion

Earlier methods for determining the physiologic variations of the venous angle in relation to the shape and size of the cranium have already been described None of them appears to have given acceptable results from the diagnostic standpoint, and the reasons are discussed in connection with the description of the different techniques The method that seems the best from the aspect of the relevant ellipse area (SCHMITT-WITTKAMP & ROSCHER) was tested by the present author and was found to be unsatisfactory in an unreasonably large number of cases, an error is also inherent in this method It was therefore necessary to find a technique that would lead to the construction of a topogram having the smallest possible area Trials with various coordinate systems based on different craniometric points indicated that a rectangular system that took into account the length and height of the cranium but was not dependent on the highly variable

'fixed points' would be the most suitable technique It was also obvious that the base line of the system should run through the tuberculum sellae, preferably in such a way that the foot of the venous angle vertical (BP) lay close to the tuberculum The line from the nasion to the opisthion, both of which are nearly always well defined, seemed suitable as the direction line

Variations in the relation of the nasion to the opisthion may of course affect the direction of the base line and have a rotatory effect on the coordinate system, but this is so small that it can be neglected The other lines, which form as it were a frame around the skull by making tangents, perpendicular or parallel to the base line, with the anterior, superior and posterior outlines of the cranium, take into account its length and height A factor having a negative effect on the covariation between coordinates is the relatively large variations in the length of the posterior part of the skull (Fig 9) and in the upward convexity of the parietal bones This is especially true of the covariation between basal distance and total height, which is definitely worse than the covariation between frontal distance and total length In all probability variations in the sella turcica and tuberculum sellae also contribute to this effect The writer has not found any way of eliminating these factors

The two charts (Fig 6) demonstrate that the venous angle amplitudes around the O lines are constant which means that relatively speaking the distribution range (prediction area) is larger for small than for large skulls To state the variation range in the two major directions as a percentage of total length and total height, respectively, proved to be unsuitable, since the amplitudes around the O lines would then increase with increasing total measurements, with the result that the prediction areas would be much greater for large skulls This would not correspond with reality, furthermore, it would then not be possible to construct an ellipse of an area applicable to all skull sizes

The method is relatively simple Six parallel lines must be drawn, four distances measured, and the position of the venous angle determined in the two charts With the aid of the value pair obtained, the position of each venous angle can be determined both with respect to distance and direction in relation to the calculated 0 point

## Conclusion

The physiologic range of variation (prediction area) for the venous angle in the median sagittal plane is elliptic The axis of the ellipse cuts the base line of the measuring system at an angle of 45° The ellipse area calculated for 99 % probability (P = 0 01) is 169 mm², its long axis measuring 16 4 mm, and the short axis 13 2 mm The corresponding values for 95 % probability (P = 0 05) are 110 mm², 13 4 mm and 10 5 mm

## Statistical calculations

*Estimations* Regression analysis based on 216 measurements gave the relations

$h = 14.5 + 0.4395H + \varepsilon$

$l = 4.7 + 0.3914L + \delta$

where $h$, $H$, $l$, $L$ are defined as shown in Fig 5 and $(\varepsilon, \delta)$ are assumed to have a bivariate normal distribution with zero means

$$(\varepsilon, \delta) \sim N(0,0, \sigma_\varepsilon, \sigma_\delta, \varrho)$$

The parameters $\sigma_\varepsilon$, $\sigma_\delta$ and $\varrho$ have been estimated to

$\sigma_\varepsilon = 2.45$ (actually 2.43)

$\sigma_\delta = 2.45$ (actually 2.47)

$\varrho = 0.254$

*Prediction areas* Using results from multivariate analysis prediction areas will be constructed for a new healthy patient's deviations from the regression lines

Let

$$Y_i = \begin{pmatrix} \varepsilon_i \\ \delta_i \end{pmatrix} \qquad i = 1, 2, \ldots n \quad n = 216$$

be the measured deviations from the regression lines We now make the simplifying assumption that $Y_i$ are independently normal distributed Then

$$\bar{Y} = \frac{1}{n} \sum_1^n Y_i$$

and

$$S = \frac{1}{n-2} \sum_1^n (Y_i - \bar{Y})(Y_i - \bar{Y})'$$

are independent

Let now

$$Y = \begin{pmatrix} \varepsilon \\ \delta \end{pmatrix}$$

be the deviations from the regression lines of a new healthy patient who is to be measured Then

$$(Y - \bar{Y})' S^{-1} (Y - \bar{Y}) \cdot \frac{n(n-2)}{(n+1)(n-2) \cdot 2}$$

is distributed according to the F distribution with 2, $n$-2 degrees of freedom

This gives the following ellipses within which $Y$ will fall with 95 % respectively 99 % probability

$\varepsilon^2+\delta^2-0.508\,\varepsilon\delta=34.8$ 95 % area

$\varepsilon^2+\delta^2-0.508\,\varepsilon\delta=53.9$ 99 % area

## Acknowledgements

The author wishes to thank Mr Urban Hjorth who carried out the statistical analysis of the data This investigation was supported by a grant from the Faculty of Medicine of the University of Umeå

## SUMMARY

Attention is drawn to the importance of the deep cerebral veins in the diagnosis of space-occupying lesions or other pathologic states by cerebral angiography and a brief description of the normal anatomy and variations of these vessels is given The so-called false venous angles are discussed The author presents his own method for determining the physiologic range of variations in the position of the venous angle in the median sagittal plane

## ZUSAMMENFASSUNG

Der Wert der tiefen Gehirnvenen fur die Beurteilung expansiver und anderer pathologischer Veranderungen des Gehirns bei cerebraler Angiographie wird betont Die Anatomie dieser Gefasse und deren Variationen werden kurz beschrieben und besondere Aufmerksamkeit wird dem s g falschen Venenwinkel gewidmet Der Autor gibt seine eigene Methode zur Abschatzung des physiologischen Bereiches der Variationen in der Lage des venosen Winkels in der medialen Sagittalebene an

## RÉSUMÉ

L auteur attire l attention sur l importance des veines cerebrales profondes dans le diagnostic par angiographie cerebrale des processus expansifs ou des autres etats pathologiques et fait une brève description de l anatomie normale et des variations de ces vaisseaux Il étudie ce qu on appelle les faux angles veineux L auteur presente sa methode personnelle pour determiner l intervalle physiologique des variations de la position de l angle veineux dans le plan sagittal médian


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FROM THE ROENTGEN DEPARTMENTS (DIRECTOR HENRY W. GILLESPIE), OF THE NORTH WEST SURREY GROUP OF HOSPITALS, THE INSTITUTE OF DIRECTORS AND B U P A MEDICAL CENTRE, LONDON, ENGLAND

# ROUTINE ABDOMINAL RADIOLOGY IN PERIODIC HEALTH EXAMINATIONS

by

HENRY W GILLESPIE

Periodic health examinations have four main objects detecting disease, establishing a baseline from which subsequent changes can be accurately assessed, forming the basis of research into normality for various groups of the population, and of reassuring the patient that, in the present state of our knowledge, he or she is in reasonably good health

Chest radiography is an established procedure in presymptomatic diagnosis, but abdominal radiographic survey, although considered necessary with urography and cholecystography, is not widely used as a routine procedure In the United States a survey of 500 abdominal examinations in patients over 40 years of age, revealed significant, yet clinically unapparent pathology in seven per cent (ROSENBAUM, LIEBER, HANSON & PELLEGRINO 1964) Abdominal radiography fits in well with other screening tests, such as a detailed medical and environmental history, cardiography, exercise cardiograph[illegible]

[illegible] abdominal roentgen survey provides however

Submitted for publication 8 September 1969

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**Table 3**

*Percentage of congenital spinal abnormalities in cases with and without backache*

| | Congenital abnormalities | | No congenital abnormalities | |
|---|---|---|---|---|
| | Cases | Per cent | Cases | Per cent |
| Backache | 30 | 5 | 538 | 95 |
| No backache | 190 | 5 | 3 769 | 95 |
| Total | 220 | 5 | 4 307 | 95 |

**Table 4**

*Percentage of scoliosis in cases with and without congenital spinal abnormalities*

| Age group | <35 | 35—44 | 45—54 | 55—64 | >65 | Total |
|---|---|---|---|---|---|---|
| No congenital abnormality | 6% | 6% | 7% | 9% | 7% | 7% |
| Congenital abnormality | 17% | 18% | 18% | 19% | 67%* | 19% |
| Total | 6% | 6% | 7% | 9% | 8% | 7% |

* The figure is unreliable owing to the small number of cases

in frequency with the age groups, may not be of clinical significance, but in several instances the position of such calculi may indicate enlargement of the prostatic gland, with subsequent urography demonstrating retention of contrast medium in the bladder after micturition The absence of gas or displacement of gasfilled organs has often led to further investigation and the persistent presence of excess gas proximal to the sigmoid colon has sometimes been the first indication of stenosing or inflammatory lesions However, in the majority of patients, excess of intestinal gas may prove to be a constitutional factor and remain remarkably constant over the years The persistent distribution of the intestinal gas in some individuals as part of their body build emphasises the difficulty in reducing the intestinal gas either by diet or medication as a preliminary to radiographic abdominal procedures

Although a survey of the skeletal system from an anteroposterior radiogram of the abdomen is limited, it provides information on congenital, positional, or degenerative changes in the lumbar spine which, if clinically necessary, will lead to extended examination of the lower part of the spine Similarly, the pelvis in an abdominal radiogram may afford an indication of any changes in

**Table 1**

*Percentage of positive findings in abdominal survey films of male executives*

| Age group | <35 | 35—44 | 45—54 | 55—64 | >65 | Total |
|---|---|---|---|---|---|---|
| Number of cases | 448 | 1 539 | 1 560 | 882 | 98 | 4 527 |
| Urinary or biliary calculi | 0 % | 1 % | 1 % | 2 % | 5 % | 2 % |
| Excess gas in gut | <1 % | 1 % | 1 % | 2 % | 1 % | 1 % |
| Prostatic calculi | 1 % | 4 % | 7 % | 10 % | 13 % | 6 % |
| Scoliosis | 7 % | 6 % | 8 % | 10 % | 7 % | 7 % |
| Congenital spinal abnormalities | 4 % | 5 % | 5 % | 5 % | 3 % | 5 % |
| Degenerative bone changes | 1 % | 2 % | 7 % | 19 % | 36 % | 8 % |
| Arterial calcifications | 0 % | 1 % | 6 % | 14 % | 29 % | 6 % |

**Table 2**

*Percentage of backache with skeletal degenerative changes*

| Age group | <35 | 35—44 | 45—54 | 55—64 | >65 | Total |
|---|---|---|---|---|---|---|
| Number of cases | 448 | 1 539 | 1 560 | 882 | 98 | 4 527 |
| Backache | 2 % | 7 % | 10 % | 25 % | 25 %* | 568 13 % |
| No backache | 1 % | 2 % | 6 % | 17 % | 37 % | 3 959 7 % |

* The figure is unreliable owing to the small number of cases

a range of information on the gastro-intestinal, skeletal, and vascular systems, as well as on the genito-urinary tract, and may moreover reveal a significant number of hidden changes

Table 1 presents positive findings in routine abdominal survey films in a series of 4 527 men, according to age groups, examined during the last four years Whilst the detection of latent abnormalities is of particular importance in the lower age groups, as is to be expected, there is a proportionate increase of abnormalities in older men

Conventional radiography will reveal alteration in the size and position of soft-tissue organs, such as the kidneys, liver or spleen, or the presence of a space-occupying lesion In 18 out of a series of 2 000 routine abdominal films, alteration of the renal outline led to further investigation by urography with positive results Equally the detection of renal stones or gallstones will not only require further radiographic and clinical investigation, but may lead to reassessment of clinical symptoms that previously were considered insignificant by the patient or examining doctor The presence of prostatic calcifications, increasing

**Table 7**

*Percentage of arterial calcification and ECG in cases with calcification of the iliac arteries*

| Age group | <35 | 35—44 | 45—54 | 55—64 | >65 | Per cent of total calcifications |
|---|---|---|---|---|---|---|
| Normal ECG | — | 1% | 6% | 14% | 14% | 5% |
| Minor abnormality of ECG | 1% | 2% | 7% | 13% | 35% | 8% |
| Major abnormality of ECG | — | 8% | 7% | 22% | 29% | 13% |

of the right and left internal and external iliac arteries lend support to the postulation that arterial calcification is not only due to disturbed lipid metabolism but also a mechanical one, a view that has been held by pathologists from the last century In a flowing system such as the arteries, static zones form at arterial 'L' and 'Y' branchings, as has been demonstrated by experimental evidence (Fox & Hugh 1966 and 1969) Mesenteric calcifications, phleboliths, or ureteric stones are a differential diagnostic alternative to calcifications in the iliac arteries, but calcified plaques, which frequently tend to be bilateral and at the same level, usually provide little diagnostic difficulty There is an association between arterial iliac calcifications and a raised blood pressure in all age groups With arterial iliac calcifications, in the total age group four per cent had a systolic blood pressure of less than 145, but ten per cent had systolic blood pressure of more than 145 There is also a statistical higher mean value of cholesterol level in those with calcification in the iliac arteries as compared with those with no evidence of arterial calcification With normal ECG findings an incidence of five per cent of arterial iliac calcifications was found In patients with a minor ECG abnormality the incidence of arterial iliac calcifications rose to eight per cent, and with a major ECG abnormality to thirteen per cent In the clinically significant group between 35 and 44 years of age, one per cent arterial iliac calcifications were found with a normal ECG, but the ECG group with a major abnormality had an incidence of eight per cent The relationship of electro-cardiographic abnormalities and arterial iliac calcifications is thus a significant and sometimes early diagnostic factor in the detection of degenerative cardio-vascular disease

## Acknowledgements

The author would like to thank H B Wright and G Pincherle for their help in supplying the statistical computer data

**Table 5**

*Calcified iliac arteries and their relation to blood pressure*

| Age group | 35—44 | 45—54 | 55—64 | All ages |
|---|---|---|---|---|
| *Systolic blood* pressure <145 | 1 % | 5 % | 11 % | 4 % |
| Systolic blood pressure >145 | 3 % | 8 % | 18 % | 10 % |

**Table 6**

*Mean cholesterol levels in cases with calcification of the iliac arteries*

| Age group | 35—44 | 45—54 | 55—64 | All ages |
|---|---|---|---|---|
| Arterial calcification | 277 | 271 | 277 | 273 |
| No arterial *calcification* | 251 | 257 | 257 | 253 |
| t | 2 44 | 2 89 | 4 25 | 6 65 |
| P | <0 02 | <0 00) | <0 0001 | <0 0001 |

the sacro-iliac and hip joints Radiologic changes due to osteoarthrosis of the lumbar spine have *little bearing on the severity of* backache, but the figures *in* Table 2 *indicate a relationship of osteoarthrosis and the presence of* backache in all age groups

Congenital abnormalities in the spine, especially the transitional lumbosacral vertebra, are frequently a pre-disposing factor in disc prolapse (GILLESPIE 1949), although there is no reliable evidence that a congenital abnormality is a cause of backache On the other hand, the presence of congenital abnormalities, such as a transitional lumbosacral vertebra, spina bifida, or six lumbar-type vertebrae, bears a relationship with lumbar scoliosis in all age groups

The presence of early arterial calcification in abdominal radiography provides an important clue to cardio-vascular degeneration, which is of special significance if found in a younger age group It is a pointer to cardio-vascular disease, to be corroborated by other clinical findings such as raised blood pressure, increased serum cholesterol concentrations or abnormal cardiographic findings The walls of the iliac arteries are favourite sites for early calcifications and frequently contain calcified plaques before they are apparent in the dorsal or abdominal aorta or in the peripheral vessels The reasons for early calcification at the bifurcation of the right and left common iliac arteries and again at the bifurcation

FROM THE DEPARTMENT OF CLINICAL CHEMISTRY (DIRECTOR B EKMAN) AND THE ROENTGEN DEPARTMENT (DIRECTOR B JENNISCHE), CENTRAL COUNTY HOSPITAL, VANERSBORG, SWEDEN

# ROENTGENOLOGIC-PHOTOMETRIC METHOD FOR BONE MINERAL DETERMINATIONS

by

B EKMAN, K G LJUNGQUIST and U STEIN

The roentgen absorption of bone depends largely on its mineral content, which consists mainly (about 85 %) of calcium phosphate (hydroxyapatite) Roentgenologic 'bone density determination' would thus provide an approximate indication of the calcium content of a bone and enable mineral depletion or deposition to be followed

The calcium content of a bone may be specifically measured by monochromatic roentgen radiation within the wave length range in which calcium gives an absorption maximum The limitations of present methods have been discussed by JACOBSSON (1964), inter alios Another principle has been used by OESER & KROKOWSKI (1961) who obtained a high calcium specificity by measuring the difference in absorption between exposures at 45 kV and 250 kV This calls however for technical equipment that is complicated, expensive, and not available outside special research centres The same applies to the approach by CAMERON & SORENSON (1963) who used iodine 125 as an essentially monochromatic radiation source

Many investigators have made use of conventional roentgen apparatus for

Submitted for publication 20 March 1969

## SUMMARY

Over 4 000 routine abdominal films of healthy men of all ages examined during a period of four years have been reviewed The figures presented suggest that *in clinical diagnostic* terms this procedure is of value Changes in bones and joints soft tissues and the digestive and urinary tracts can be assessed and there is a significant relationship between arterial iliac calcification and the blood pressure cholesterol level and ECG abnormalities

## ZUSAMMENFASSUNG

Eine Durchsicht von 4 000 Routineaufnahmen des Abdomens bei Gesunden aller Altersklassen wurde unternommen Die Resultate zeigen dass solche Filme von klinisch diagnostischem Wert sind Veranderungen in den Knochen und Gelenken Weichteilen im Magen darmkanal und im Nierensystem konnen abgeschatzt werden Es besteht z B ein bedeutsamer Zusammenhang zwischen der Verkalkung der Beckenarterien und dem Blutdruck dem *Cholesterolniveau und elektrokardiographischen Abweichungen*

## RÉSUMÉ

L auteur a passe en revue plus de 4 000 radiographies de l abdomen d hommes en bonne sante de tous ages examines au cours d une periode de quartre ans pour des examens de sante systematiques Les resultats font penser que cette technique presente un intéret en matiere de diagnostic clinique On peut deceler des modifications du squelette des articulations *des parties molles et des appareils digestif et urinaire il y a une relation significative* entre la calcification des arteres iliaques et la pression arterielle le taux de cholesterol et les anomalies ECG

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quantitatively estimating the radiation absorption by the mineral content of bone in a positive or negative roentgen image (see, for instance, OMNELL 1957, NORDIN & SMITH 1965) The problems involved will be considered

*Reproducibility and standardization* The absorption effect of the mineral content of bone on the negative or positive roentgen image is affected by exposure time, voltage, screens, type of film for the primary image and the positive print, as well as by the processing and printing technique Despite advanced automation in roentgen apparatus and processing procedure, and the uniform quality of modern films, the direct correlation of roentgen absorption with mineral content, as it appears in the final image, is impossible The investigated bone should therefore at each analysis be compared with a standard and the results expressed as a percentage The choice of a standard has been thoroughly examined According to OMNELL (1957) roentgen rays are absorbed by aluminium to the same degree as bone mineral It is thus possible to express the results in millimetre aluminium or, if required, in bone mineral content, for example as hydroxyapatite

*Soft tissue effect and secondary radiation* By the choice of adequate radiation quality and suitable film the influence of soft tissue on the negative and positive roentgen image can be much reduced According to SCHMID (1963), the soft tissue effect is negligible under certain conditions for instance in the examination of the phalanges of the hand

KEANE et coll (1959), working with the radius and ulna, i e bones surrounded by thick layers of soft tissue, could avoid most of the side effects by placing the forearm together with the standard in a tank of water and by having an exit distance between arm and standard in the water tank and the film (the same arrangement as in Fig 6) Even then they had to correct for soft tissue effects in their calculations

*Photometric evaluation* Earlier investigators usually employed densitometric determinations pointwise or over defined areas of the bone investigated However, great difficulties are experienced in anatomically defining the measurement area from one patient to another To make the measurement independent of the anatomical bone size, two films must be obtained one for densitometry and one for measurement of the diameter where the bone is traversed by the beam

## Preliminary methodologic investigations

Working with the radius and ulna we found that when an aluminium standard was placed at the side of the forearm, secondary radiation and

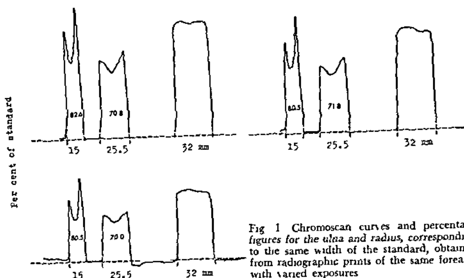



Fig 1 Chromoscan curves and percentage figures for the ulna and radius, corresponding to the same width of the standard, obtained from radiographic prints of the same forearm with varied exposures

scatter effects produced appearances that varied widely from one roentgenogram to another Despite repeated attempts, this source of error could not be eliminated by enclosing the standard in a phantom — The best results were obtained with a phantom composition, mix D, according to JONES & REINE (1949), consisting of 60 8 % paraffin, 30 4 % plastic material (Alkathene Polymer WRM-19, ICI), 2 4 % titanium dioxide and 6 4 % magnesium oxide — Using the Keane technique however, with the forearm enclosed in a tank of water, we obtained reproducible films of the standard and, as indicated by KEANE, the soft tissue effects became considerably lower

Soft tissue consists of approximately 75 % water, the rest being organic matter with a low roentgen absorption approaching that of water However, the extra and intracellular water contains a wide variety of electrolytes, and the present approach was an attempt to eliminate completely the soft tissue effects by adding adequate amounts of quantitatively dominating sodium chloride to the water in the tank

Difficulties in earlier employed densitometric measurement techniques appeared to be avoided by measuring the blackening in the positive image from a bone cross section by photometric scanning and *expressing thus in relation to the* blackening of the corresponding cross section width of the standard used This can be easily accomplished technically by employing the same type of photometric scanning equipment that is used at evaluation of electrophoresis strips The Chromoscan Mark I (Joyce, Loebl & Co Ltd, Gateshead-on-Tyne, England),

quantitatively estimating the radiation absorption by the mineral content of bone in a positive or negative roentgen image (see, for instance, OMNELL 1957, NORDIN & SMITH 1965) The problems involved will be considered

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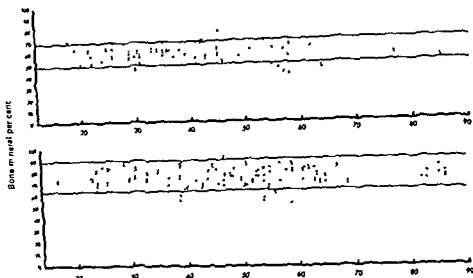



Fig 3 Referen... ject represented... corresponds to a...

tank Fig 2, in which the aluminium thickness is plotted against Chromoscan readings, shows that full linearity is obtained, although lighter or darker prints were produced by deliberately varying the exposure time in the copying procedure

The reproducibility of the method was investigated in twelve separate determinations of the bone mineral percentage in a section of a foreleg of a pig The mean was found to be 81 9 with SD 3 4 and a coefficient of variance of $\pm$ 4 1 %

The problem was then, with a reasonably simple and reproducible method available for determining the roentgen ray absorption of bone tissue, what the clinical and biologic significance of its use would be

In diseases with a reduced mineral content in the skeleton, and when the conventional roentgen technique is employed, this depletion is mainly observed in the spinal column Considerable variations in the mineral content are however necessary before such changes can be recorded, figures in the order of 30 to 50 % usually being suggested Although changes in the mineral content are perhaps most marked in the spinal column, it seems probable that if caused by diet or by endocrine factors they will affect the skeleton as a whole and can be demonstrated provided a sufficiently sensitive method can be employed.

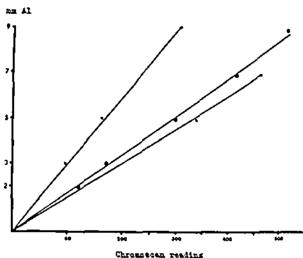



Fig 2 Correlation between aluminium layer thickness and Chromoscan readings at different exposure times

a double beam recording and integrating reflection photometer that makes it possible to integrate numerically any chosen part of the areas under the density curves, was chosen for our purpose

The forearm of the patient and an aluminium standard, in fixed positions in 0 86 % saline, 10 cm in depth, are roentgenographed at suitable voltage and exposure time with a hard film, eliminating the effects of soft tissue Secondary radiation effects are relatively slight because of the 30 cm space between the water tank and the cassette holder (see Fig 6)

The blackening in the positive film is determined in two cross sections, one at the centre of the radius and ulna and the other in the vicinity of the distal joint heads by scanning with the Chromoscan The degree of blackening of the bones is expressed as a percentage of the blackening of a corresponding width of the aluminium standard By suitable shaping of the wedge in the Chromoscan linearity between the degree of blackening and the thickness of the plates in a series of aluminium standards can be obtained The technical procedure is described later

The control experiments indicated that by varying the exposure time at copying, but keeping other conditions constant, prints with different blackening will be obtained This does not however affect the measurement results (Chromoscan readings of the bone curves as percentages of the readings of corresponding widths of the aluminium standard) A typical example is given in Fig 1

Linearity between the roentgen absorption and the Chromoscan readings was controlled by roentgenographing a series of aluminium plates, of different thicknesses but otherwise of the same shape, arranged side by side in the

**Table 1**

*Comparison of bone mineral percentages for the left and right arms*

| Number of patients | Right or left handed | Mean values and left/right ratios | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Radius | | | | Ulna | | | |
| | | Strip-I | | Strip-II | | Strip I | | Strip-II | |
| | | Left | Right | Left | Right | Left | Right | Left | Right |
| *10 females* | Right | 47.7 | 52.6 | 52.2 | 57.5 | 46.1 | 51.1 | 51.7 | 58.3 |
| | | 0.91 | | 0.91 | | 0.90 | | 0.89 | |
| 10 males | Right | 67.0 | 70.6 | 78.2 | 80.9 | 64.5 | 67.2 | 81.4 | 84.4 |
| | | 0.95 | | 0.97 | | 0.96 | | 0.96 | |
| 2 males | Left | 60.0 | 55.6 | 71.8 | 64.6 | 58.8 | 50.9 | 81.8 | 72.9 |
| | | 1.08 | | 1.11 | | 1.15 | | 1.12 | |

might not per se imply mineral disorders), and whom for several years had been given cortisone preparations without accompanying treatment with calcium preparations or anabolic steroids, were therefore investigated. The values of most of the patients lay within the lower part of the normal range. Those judged clinically to be suffering from osteoporosis were far below (Fig. 4, a and b). Partial gastrectomy may result in malabsorption of calcium (HARVALD, KROGSGAARD & LOUS 1962). Bone mineral percentages for males who had had Billroth II operations are given in Fig. 4 c. They all have readings below the mean value and most of them around the lower normal range.

Like KROKOWSKI & STEINER (1961) we regularly found higher values of the mineral content in the right than in the left arm in right handed subjects and vice versa (Table 1). KEANE et coll. (1959) pointed out the dependence of calcium deposition on mechanical factors which might well explain the findings.

The well known fact that immobilization results in a reduction of calcium is illustrated in Fig. 5, which gives the bone mineral percentages in a patient with a radius fracture of the right arm on the day it occurred, after 24 days immobilization, and again after a further 19 days convalescence. It is obvious that, whereas values in the undamaged left arm were constant or somewhat increased, a substantial reduction occurred in the right arm, even during the short immobilization period, followed by a return to the initial values.

These results — the low values in bone mineral content in clinically diagnosed osteoporosis, and the decrease during cortisone medication, after gastrectomy,

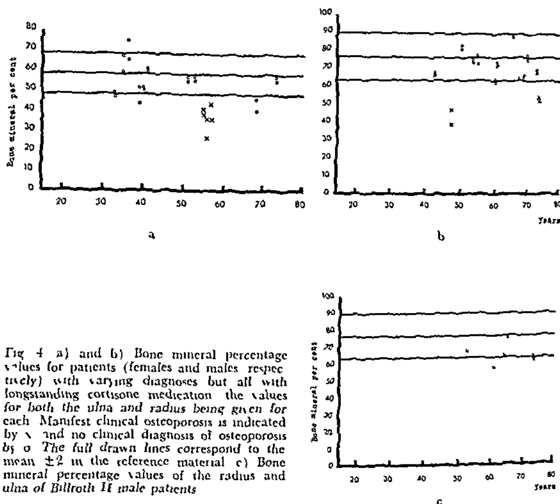


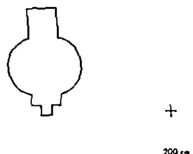

Fig 4 a) and b) Bone mineral percentage values for patients (females and males respectively) with varying diagnoses but all with longstanding cortisone medication the values for both the ulna and radius being given for each Manifest clinical osteoporosis is indicated by x and no clinical diagnosis of osteoporosis by o The full drawn lines correspond to the mean ±2 in the reference material c) Bone mineral percentage values of the radius and ulna of Billroth II male patients

The best way to test the method seemed to be to investigate the clinical conditions in which changes in the bone mineral content might be expected

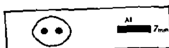
A preliminary reference series of 61 females and 80 males of different ages was collected The results are given as bone mineral percentages in Fig 3 For definition and calculation, see p 316 The mean ± 2 SD is the normal range

As can be expected in a reference series of hospital subjects, a few patients lie outside the normal range (5 females and 4 males) Closer analysis of these revealed that most of them had histories of dietary insufficiences The female with the lowest values, for instance, was an alcoholic who had lived for a long period mainly on red wine and industrial spirit

As is well known, cortisone therapy may result in a reduced bone calcium content Patients admitted to the hospital under varying diagnoses (which usually




PLEX GLAS CONTAINER




10 cm

30 cm

CASSETTE AND INTENSIFYING SCREENS

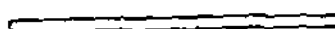


Fig 6 Arrangement of the equipment and some technical data Exposure with 70 kV, 200 mA and 0 1 second

The arrangement during exposure is illustrated in Fig 6 together with the technical data

*Procedure* The forearm is placed in a plexiglas container filled with sodium chloride solution The inner base is 10 × 30 cm and the height 40 cm The *lower part contains* a plastic tube that the patient grips, the tube being furnished with a collar to ensure that the arm is in a position fixed in relation to an aluminium standard (0 7 cm × 2 7 cm × 23 cm) in the container The central ray must be directed through the centre line of the forearm Films of the left and right arms are obtained A 0 86 % sodium chloride solution is used and it has proved practical to add 7 5 g metagin and 2 5 g nipasol per 10 litres to prevent rapid bacterial growth

Standard cassettes with intensifying screens keep the radiation hazards to a minimum Gevaert Curix roentgen film, emulsion type T, and a standard automatic processing unit are employed Two parallel-coupled knives cut the film into 27 mm strips for the Chromoscan holder, a marking arrangement indicating suitable lengths of strip To ensure that these will correspond anatomically to comparable parts of the radius and ulna in different subjects, the

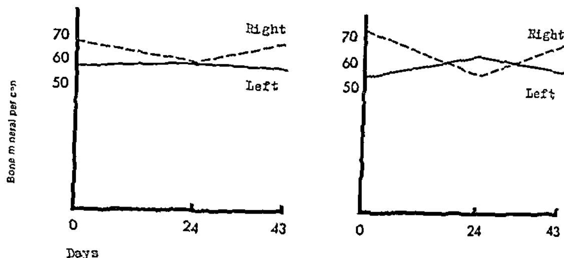



Fig 5. Bone mineral percentage values of the radius (left) and ulna (right) from a woman on the day of fracturing the *right radius* after 24 days immobilization and after an additional 19 day period of convalescence

during immobilization, as well as the higher mineral content of the bones on the work hand side — may be regarded as establishing the clinical usefulness of the method

The necessity of evaluating positive copies instead of the original roentgen films must however involve the added errors and the extra manual work of an additional photographic procedure, and the disadvantage of photometrically measuring reflected light in place of transmitted light Our work was performed during the period 1964—1966, and in 1966 the new Chromoscan Mark II became available This model has been designed also for transmittance measurements, the new feature was taken advantage of and by simply turning the (transparent) grey wedge 180° it was possible to make the apparatus read (and give integrals of) white instead of black areas It thus became possible to obtain Chromoscan readings direct from the original negative roentgen film

## Present method

*Principle* of measurement The modified method differs from the preliminary version used in the photometric measurements The roentgen absorption by bone or standard is measured directly in the film with the aid of a Chromoscan Mark II transmittance photometer which after reversing the grey wedge gives positive curves and readings of the negative bone and standard image in the film

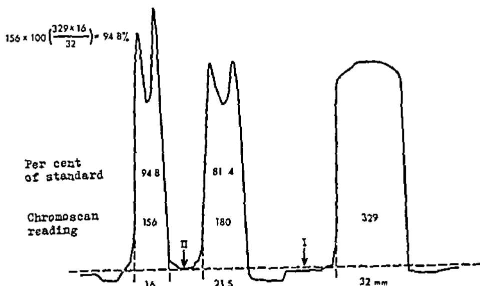



Fig 8 Chromoscan curves corresponding to strip from film of ulna, radius and standard

The apparatus is set at zero at a point a few centimetres from the standard, between this and the soft tissue of the arm (Fig 8, arrow-I) The apparatus is thus constantly at zero on the water layer With the chosen saline concentration, an even base line for the fluid and for the soft tissue between the radius and ulna is obtained, with a deviation only for the layer of fat of the soft tissue which appears as downward curves at the base line of Fig 8

The base line is drawn out (as seen in Fig 8) and with our technique a width of the standard of 32 mm is obtained The width of the radius and ulna is measured at the level of the base line with a pair of calipers graded to 0 1 mm As may be seen from the figure, the straight lateral parts of the bone curves are drawn down towards the base line to eliminate difficulties of measurement caused by the rounding of the bone contour immediately next to the base line

In extremely obese or thin people, some level difference may appear between the soft tissue line lying between the radius and ulna (Fig 8, arrow-II) and that part of the base line that corresponds to the fluid (arrow-I) If this exceeds 6 mm, two zero adjustments are made the normal at arrow-I for scanning the standard and another at arrow-II, based on the soft tissue between the radius and ulna, for scanning the bones

The integration figures are noted for the curves of the standard and for

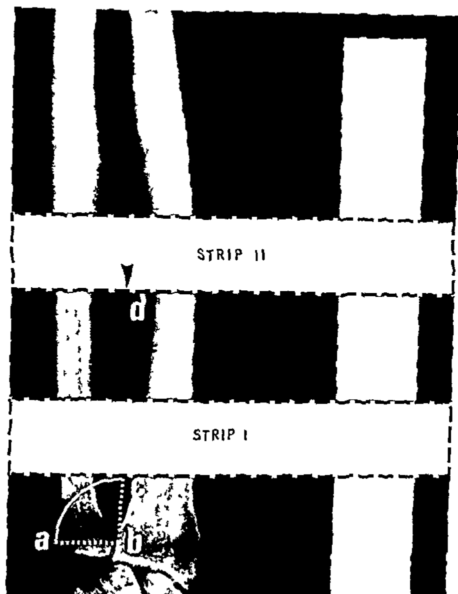



Fig 7 Positioning of the strips

greatest width of the distal joint of the ulna is measured This length (A—B) (Fig 7) is plotted along the ulna, the first strip being cut from point C The measured distance A—B is quadrupled, and strip No 2 is cut from point D Thus two strips are obtained one corresponding to a more cancellous bone and the other to a bone in which the compact tissue dominates The film strip is placed in the holder of the Chromoscan Mark II adapted for transmittance measurements and with its grey wedge turned 180°, as described Filter 2 5 D and a slit measuring 1 mm × 10 mm are the rule

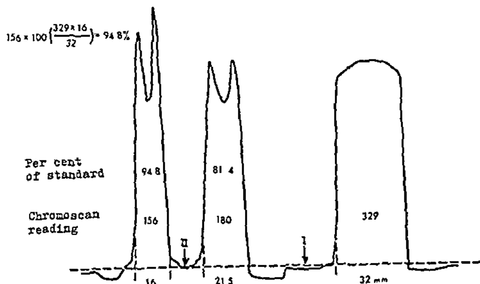



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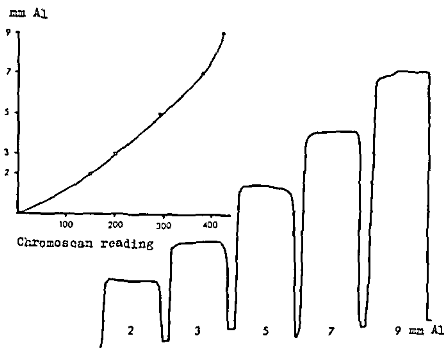



Fig 9 Chromoscan chart of a series of aluminium plates and the curve obtained by plotting Chromoscan readings against aluminium layer thickness Uncorrected cam

the radius and ulna The integration value for each bone is calculated for the corresponding width of the standard, the integration value of the radius and ulna is then expressed as a percentage The values obtained in such calculations are exemplified in Fig 8

*Experimental* The roentgen absorption of soft tissue is mainly conditioned by its water and electrolyte content The fat in the subcutaneous layer and the bone marrow has a lower roentgen absorption, however This may explain that 0 86 % saline gave the best equalizing effect, even though the total electrolyte roentgen absorption effect in homogenous soft tissue is higher than that corresponding to the saline concentration chosen

Exposure time, voltage, type of film, processing procedure, zero adjustment routine, and the effect of base line variations at the Chromoscan measurements were all subjected to detailed investigations

Ten routine kilovoltage settings were carried out on the apparatus used (Elema Schonander Optimat), and the electrical output differences (with the actual tube load) proved to be less than ± 2 % at a nominal 70 kV

The reading range' in the film was densitometrically determined and found to be within 1 and 2 in density (i e the darkest spot on the film a little below

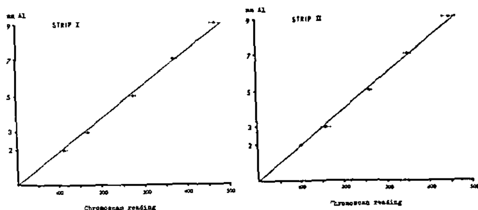



Fig 10 Mean values with their SD s of the transformed Chromoscan readings from eleven films of the same series of aluminium plates plotted against aluminium layer thickness Corrected cam.

2 and the brightest a little over 1) This means that the fogging of the film within normally accepted ranges has little or no effect on the measurements Tests with new and old film of the same type disclosed no definite tendency

The use of intensifying screens introduces possible errors, but without them it was not possible to obtain a sufficient density although different film types were tested With the best film, a 20 fold increase in radiation exposure gave densities ranging from 0 6 to 1 4, which is far too low It proved practical to have four cassettes with screens, used exclusively for this kind of work, thus keeping wear down to a minimum The screens are picked from the same emulsion number and 'cross tested' against each other Any changing of screens owing to wear naturally demands recalibration of the Chromoscan readings, as does any change of films (emulsion number or type)

Geometric problems and the heel effect were studied, and it was found that by keeping the object and the standard always in the same fixed positions in relation to each other and to the central roentgen beam, the measurements gave reproducible results. Model experiments with isolated bones indicated that variations in projection did not change the measurement results

A detailed presentation of the experiments is outside the scope of this paper It may be assumed however that the accumulated effect of the different sources of error could be demonstrated in studies of linearity and the reproducibility of the measurements

1 *Linearity* A series of aluminium plates were arranged in the container with the 7 mm plate in the same position as when it was used as standard

**Table 2**

*The reproducibility of the method*

| Bone mineral percentage 12 separate determinations | Strip I | | | |
|---|---|---|---|---|
| | Radius | | Ulna | |
| | *Left* | *Right* | *Left* | *Right* |
| Technician I | | | | |
| Mean | 61 8 | 67 4 | 66 5 | 67 0 |
| SD | 2 4 | 3 3 | 3 2 | 4 2 |
| Variation coefficient | 3 8 | 4 8 | 4 8 | 6 3 |
| Technician II | | | | |
| Mean | 59 9 | 67 3 | 65 0 | 67 5 |

in the bone measurements, and with the thinner plates covering the position occupied by the forearm

The blackening of the film as a result of roentgen absorption by bone or the aluminium standard (both of which affect the roentgen beam alike (OMNELL 1957)) depends on the quality of the roentgen beam and the characteristic film response curve varying from one type of film to another A 'cam' in the Chromoscan *controls the pen deflection that results from the* effect of the light beam on the photomultiplier By varying the profile of the cam, it is possible to change the relation between the pen deflection and the blackening to be measured This means that every film response curve can be adjusted to linearity by means of the cam

Fig 9 is a typical reproduction of the Chromoscan chart and the non linear curve obtained by plotting the chromoscan integrated readings against the thickness of the aluminium plates A linear standard cam was used in this case

A new cam was constructed, partly calculated according to ALBERT RECHT & OWEN (1964) and partly empirically by repeated measurements of the aluminium plate series and successive changes of the cam It was thus possible to obtain *perfect linearity even in the preliminary two step film positive print* method (Fig 2)

In order to study possible effects of technical and instrumental variations on linearity in repeat measurements with the present method, the aluminium

Table 2 *(cont )*

| Strip-II | | | | Means of | | | |
|---|---|---|---|---|---|---|---|
| Radius | | Ulna | | Radius Strip I+II Left + Right | Ulna Strip I+II Left + Right | Strip-I Radius + Ulna Left + Right | Strip-II Radius + Ulna Left + Right |
| Left | Right | Left | Right | | | | |
| 75 8 | 78 8 | 90 2 | 89 2 | 70 9 | 78 3 | 65 4 | 83 5 |
| 2 9 | 3 8 | 3 3 | 3 7 | 1 1 | 2 1 | 2 3 | 2 0 |
| 3 8 | 4 7 | 3 6 | 4 1 | 1 5 | 2 7 | 3 4 | 2 4 |
| 77 0 | 80 0 | 91 3 | 90 8 | 71 1 | 78 6 | 65 0 | 84 8 |

plate series was exposed eleven times at intervals with readjustment of the roentgen equipment between the films The resulting curves for the different films depict slopes varying according to deeper or lighter individual blackening of the films The mean slope was calculated for all the curves, for each separate curve, a factor was derived to transform the separate reading data to correspond with the curve with the mean slope

In Fig 10 are given the mean values of the transformed data from eleven films with their standard deviations plotted against aluminium layer thickness Data are given for two strips from each film, cut from the same positions as in the bone determinations A slight systematic deviation from linearity is observed in both strips This is because the cam for the film used was constructed three months before the experiment, and the deviation could be explained by the replacement of a potentiometer in the integrating circuit of the Chromoscan The deviation from the original perfect linearity probably reflects the tolerances in the manufacture of the two potentiometers Every adjustment or replacement in the Chromoscan should obviously be followed by recalibration

2 *Reproducibility* Twelve roentgenograms were taken at intervals of the left and right forearms of the same subject in order to test the reproducibility of our method Table 2 gives the means of the eight separate measurements and of groups of these with their standard deviations and variation coeffi

**Table 3**

*Mean bone mineral percentages for radius and ulna in three equivalent groups of women determined with varied techniques*

| Investigated group | Number | Mean bone mineral percentage Radius and ulna | Method |
|---|---|---|---|
| I Hospitalized females, mainly psychiatric age 18—49 years | 43 | 59 5 | Preliminary |
| II Pregnant (2nd—4th month) | 73 | 59 5 | Definite but |
| III Population study, females age 29—49 years | 94 | 58 7 | different films and cans |

cients the means of the four strip-I and the four strip-II measurements, and of the four measurements of the radius and the ulna

The mean variation coefficient for the separate measurements is ± 4 0 % The higher variation coefficients of some of the strip-I measurements depend on the more irregular contour of the bones in the vicinity of the joints and the resulting greater influence of errors in measuring the width of the bone on the base line

The mean values of the groups of measurements represent lower variation coefficients and might eliminate hazard errors, both in roentgenography (for instance, localized irregularities of the film) and in the Chromoscan measurements of the bone width

The means of the four measurements of each bone (left and right arms, strip-I and strip-II of the radius and of the ulna) showed the lowest variation coefficients and were therefore chosen to represent the results in clinical investigations and are called 'the bone mineral percentages' (The individual measurement value will thus express the roentgen ray absorption in the bone cross section investigated as a percentage of the roentgen ray absorption in a 7 mm aluminium plate of the same surface area ) The variation coefficient for the radius was ± 1 5 % and for the ulna ± 2 7 %

A comparison between the results when two technicians separately performed the whole Chromoscan procedure on the same strips also appears in Table 2 The agreement was excellent

The reproducibility of the method may be illustrated in another way by comparing the results from different but equivalent clinical materials (1) females in the reference material (Fig 3) between 19 and 49 years of age, (2) results obtained for pregnant women on their first visit to the prenatal care unit (2nd to 4th month of pregnancy) from an investigation to determine

**Table 4**

*Bone mineral percentages of different sex and age groups in a population study*

*A Females*

| Number | 44 | | 50 | | 47 | | 44 | | 38 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age groups years | 29—39 | | 40—49 | | 50—59 | | 60—69 | | 70—79 | |
| Bone | Rad | Ulna | Rad | Ulna | Rad | Ulna | Rad | Ulna | Rad | Ulna |
| Mean bone mineral % | 58.1 | 57.4 | 59.6 | 59.7 | 54.8 | 56.0 | 49.2 | 50.9 | 46.7 | 47.8 |
| Standard error of the mean | 0.86 | 0.75 | 0.92 | 1.02 | 1.08 | 1.27 | 1.16 | 1.34 | 1.57 | 1.53 |
| SD | 5.7 | 5.0 | 6.5 | 7.2 | 7.4 | 8.7 | 7.7 | 8.9 | 9.7 | 9.4 |
| Range (mean ± 2 SD) | 46.7–69.5 | 47.4–67.4 | 46.6–72.6 | 45.3–71.1 | 40.0–69.6 | 38.6–73.4 | 33.8–64.6 | 33.1–68.7 | 27.3–66.1 | 29.1–66.2 |
| Per cent of investigated below a bone mineral content of 47 % | | — | 8 | 4 | 19 | 17 | 32 | 32 | 37 | 47 |

*B Males*

| Number | 44 | | 35 | | 38 | | 46 | | 37 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age groups years | 29—39 | | 40—49 | | 50—59 | | 60—69 | | 70—79 | |
| Bone | Rad | Ulna | Rad | Ulna | Rad | Ulna | Rad | Ulna | Rad | Ulna |
| Mean bone mineral % | 69.0 | 69.1 | 68.7 | 70.3 | 66.3 | 68.1 | 65.0 | 68.1 | 64.6 | 67.9 |
| Standard error of the mean | 0.95 | 1.01 | 0.76 | 1.32 | 1.13 | 1.34 | 1.30 | 1.28 | 1.18 | 1.52 |
| SD | 6.3 | 6.7 | 4.5 | 7.8 | 7.0 | 8.2 | 8.8 | 8.7 | 7.2 | 9.2 |
| Range (mean ± 2 SD) | 56.4–81.6 | 55.7–82.5 | 59.6–77.8 | 54.7–85.9 | 52.3–80.3 | 51.7–84.5 | 47.4–82.6 | 51.7–84.5 | 50.2–79.0 | 49.5–86.3 |
| Per cent of investigated below a bone mineral content of 56 % | | — | — | 3 | 5 | 8 | 22 | 11 | 11 | 11 |

possible changes in the mineral content of bone, (3) results corresponding to females 29 to 49 years of age from a population study (see below). From a methodologic point of view, this means that the preliminary method was used (SPRING 1966) in group I and in groups II and III the definite method (SPRING & AUTUMN 1967) but with different films. Table 3 indicates good agreement between the three groups, even though for both the Chromoscan Mark I and Mark II three different films and accordingly three different cams had been used.

*Normal range of the method.* A population study was performed in order to study the possible correlations between the bone mineral percentage and

sex, age, anthropology, diet and especially calcium intake, activity and the results of a complete clinical, roentgenologic, and laboratory investigation of each participant The results will be published separately and only the data necessary to establish the normal range of the method will now be mentioned The participants were picked out by chance from the official registration records by a system that would ensure an even distribution in regard to sex, age, and origin from rural or urban areas, with a number of participants large enough to allow statistical analysis In all, 484 persons were approached and 87.4 % (426) participated Non attendance was equally distributed in different population groups

Table 4 gives the means of the determinations of the bone mineral percentage of the radius and ulna for different sex and age groups The figures are considerably lower in females than in males and, for both sexes, highest in the groups 29 to 49 years Males had a slow and females a considerable and statistically significant decrease with increasing age In both sexes, the values for the radius and ulna almost coincide in the age groups up to 49 years but thereafter, the ulna produces somewhat higher figures

The normal ranges (mean ± 2 SD) for the different age groups (Table 4) must, in a population study, be influenced by old age osteoporosis There therefore seems to be justification in choosing the mean of the ranges for the group from 29 to 49 years as the normal for the method, that is 47 to 70 % for females and 56 to 80 % for males

## Discussion

The object of the methodologic work was to develop a simple technique which, with conventional roentgenologic and laboratory equipment, would produce reproducible results corresponding to the bone mineral content

This makes it necessary to abstain from the use of monochromatic roentgen radiation, which meant that the absorption effects will not be specific for calcium This is why no attempt has been made to express the results in milligram calcium per bone area or volume The measurement figures correspond to total bone minerals of which, however calcium hydroxyapatite dominates By expressing the results as percentages of an easily defined and manufactured aluminium standard, however, it seems possible for various investigators to use the method both for diagnostic purposes and for following changes in the bone mineral concentration in the same individual, depending on pathologic changes or therapy

An attempt has been made to simplify the method by utilizing the technical possibilities of the Chromoscan instrument the measurement of bone width

is made directly on the Chromoscan curve underlying the integration reading which, by reversing the grey wedge, is made positive in evaluating the negative film Furthermore, it has been possible by changing the cam, in accordance with the principle of the Chromoscan instrument, to obtain full linearity between the integration readings and a series of aluminium standards of different layer thicknesses

The construction of the cam to be used is based on measurements of an aluminium standard series (corresponding to the aluminium step wedge in other methods for obtaining bone mineral content) placed across the area of the film employed for the bone determinations with the forearm and the 7 mm aluminium standard in fixed positions This means that the cam will eliminate the heel effect, the influence of the inhomogeneity of the roentgen beam over the exposed area and the differences in blackening effect caused by changes in the spectral composition of the beam in passing aluminium (or bone) layers of varying thicknesses

In conclusion it may be said of the control experiments that the technical specifications chosen maintained the linearity and reproducibility of the method, despite the unavoidable variations of a technical nature that must occur in the complex working procedure of both roentgenography and Chromoscan measurements This in turn depends on the main principle of the method, all technical variations will affect bone and standard alike

During the progress of our work, ANDERSSON, SHIMMINS & SMITH (1966) published a method for the measurement of the metacarpal mineral content with the Chromoscan Mark II These authors evaluated the 'density' by graphically projecting the curve of bone on that of an aluminium step wedge The density was then correlated to bone width and cortical thickness measured on the film, and a standardised aluminium equivalent' of the bone calculated (in principle corresponding to our bone mineral percentage')

We have also applied our method to metacarpal measurements. The smaller width of metacarpal bones made it necessary to change the gear controlling the speed of the chart drum in order to obtain reproducible results

A survey of methods proposed for clinical studies of changes in bone mineral contents was given by NORDIN & SMITH in their 1965 monograph The technical difficulties and low reproducibility, however, have prevented the suggested determinations from coming into general use As stated by these authors, so far no control series that permit systematical clinical investigations have been presented ANDERSSON, SHIMMINS & SMITH (1966) reported that the establishment of normal ranges for their method is in progress

KROKOWSKI & STEINER (1961), using the method of OESER and KROKOWSKI (1961) with high calcium specificity, found a decrease in calcium concentration

of the radius in ageing females, which agrees well with the decrease demonstrated in Table 4 Contrary to the present findings they observed the same tendency in males but this may be explained by the small number of more elderly males in their material (Altogether they investigated 50 females and 45 males) They found, as did the present authors, lower values for females than for males The figures for females of middle age groups amount to 87 % of the figures for males The corresponding figure in the present material is 85 5 %

Table 4 gives the percentages of subjects falling below the normal range of the method for each age group (corresponding to the age groups 29 to 49 years) For females there is a regular increase up to about 40 % for the higher age groups, whereas males present much lower percentage figures The results agree well with the frequency of senile osteoporosis reported by BECK & NORDIN (1960) and GITMAN, KAMHOLTZ & LEVINE (1958)

The main part of our knowledge concerning calcium metabolism originates from balance experiments, which, however, in principle, mainly provide in formation about the relation between Ca input and Ca output and only indirectly about deposit and depletion in the skeleton The technical difficulties and errors of calcium experiments have recently been stressed by ISAKSSON LINDHOLM & SJOGREN (1966)

The concept of osteoporosis is consequently controversial Mention will be made only of the view of the Albright School, which regards osteoporosis as being caused by an endocrinely conditioned protracted removal of the organic basic substance of the skeleton, as opposed to the increasingly widely held theory on osteoporosis as a calcium deficiency condition The slight decrease in the bone mineral content in ageing males and the considerable decrease in elderly females found in the present population study seem to emphasize en docrinologic factors, possibly the cessation of estrogen production in females after the menopause

## Acknowledgement

The authors take this opportunity of thanking E Carlstrom Lecturer at the Department of Statistics University of Gothenburg who gave the principles for sampling in the popula tion study and A Anberg and T Leonhardt for their cooperation and help The work was supported by Alvsborgs Lans Landsting and AB Leos Foundation for Research Halsing borg

## SUMMARY

A new, technically simple method of determining the mineral content of the radius and ulna is reported This demands only standard equipment for roentgen films and for photo metric scanning Normal ranges for males and females of different ages were recorded in a population study of 426 subjects and agree with those in the literature on the incidence of senile osteoporosis

## ZUSAMMENFASSUNG

Eine neue und einfache Methode zur Bestimmung des Mineralgehaltes von Radius und Ulna wird angegeben. Diese Methode erfordert lediglich normale Röntgenapparatur und zusätzlich Einrichtung für ein photometrisches Scan. Die Methode wurde an 426 Personen jeglichen Alters und Geschlechts angewandt. Die Befunde stimmten mit den in der Literatur gefundenen gut überein, auch bezüglich der Häufigkeit der senilen Osteoporose.

## RÉSUMÉ

Les auteurs présentent une nouvelle méthode techniquement simple pour déterminer la teneur en minéraux du radius et du cubitus. Elle nécessite seulement un équipement ordinaire de radiographie et de photométrie. Ils ont déterminé les variations normales chez les hommes et chez les femmes, à différents âges, dans une étude de population de 426 sujets. Ces résultats concordent avec les résultats déjà publiés dans la littérature sur la fréquence de l'ostéoporose sénile.

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FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR C J MCCAFFERY), HUTT HOSPITAL, LOWER HUTT, NEW ZEALAND

# SYNOVIAL LESIONS IN THE ADULT HIP JOINT IN RHEUMATOID ARTHRITIS

by

W J WESTON

HEFKE & TURNER (1942) published their paper Obturator sign as earliest roentgenographic sign in diagnosis of septic arthritis and tuberculosis of the hip joint' This was seen as a swelling of obturator internus on the lateral wall of the pelvis in the a p view

In 1953, DREY reported synovitis of the hip joint producing swelling of the gluteus minimus, the most medial of the gluteal muscles lying above and lateral to the joint, and of the ilio-psoas just above its insertion into lesser trochanter, below and medial to the joint

KELLGREN (1963) stated that the clinical diagnosis of early hip joint involvement in rheumatoid arthritis is difficult, because pain in the leg is so easily attributed to the more obvious concurrent disease of the knees, and small effusions in the hip are not readily demonstrated' The signs of cartilage loss and the wedge shaped appearance of the superior part of the joint space are well known signs of rheumatoid involvement of the hip

BERENS (1963) drew attention to the soft tissue signs in the early stage of hip joint lesions in rheumatoid arthritis such as capsular swelling or synovial

Submitted for publication 16 June 1969

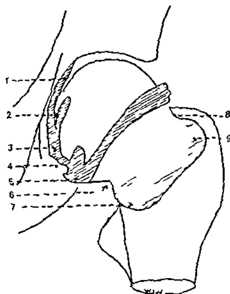



Fig 1 Line diagram of post mortem arthrogram of hip following injection of 12 ml of barium sulphate suspension 1 — recessus capitus, 2 — ligamentum teres 3 — acetabular recess, 4 — ligamentum transversum, 5 — inferior recess, 6 and 8 — zona orbicularis, 7 and 9 — recessus colli



Fig 2 Post mortem arthrogram using 25 ml of barium sulphate suspension The inferior recess is well seen caudal to the femoral neck

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR C J MCCAFFERY), HUTT HOSPITAL, LOWER HUTT, NEW ZEALAND

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KELLGREN (1963) stated that 'the clinical diagnosis of early hip joint involvement in rheumatoid arthritis is difficult, because pain in the leg is so easily attributed to the more obvious concurrent disease of the knees, and small effusions in the hip are not readily demonstrated' The signs of cartilage loss and the wedge shaped appearance of the superior part of the joint space are well known signs of rheumatoid involvement of the hip

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Fig 5 Ap and axial roentgenograms in a third case of active rheumatoid arthritis The synovial mass lesion is well seen caudal to the femoral neck in the axial view (arrows)

can be demonstrated radiographically when the soft tissues are cleared from the overlying bone

*Arthrographic anatomy of the adult hip* Arthrography of the hip joint performed in the cadaver demonstrated the normal appearance of the synovial membrane about the hip joint

The average hip at post mortem will take about 12 ml of contrast medium In one case the hip was over distended with 25 ml contrast medium The impression of the orbicular ligament was well seen, as was the bulging synovial membrane on the caudal aspect of the neck medial to the orbicular ligament (Fig 2)

The contrast medium was seen in the arthrogram as a thin layer about the femoral head The ligamentum teres may be seen on the medial aspect of the head with contrast medium each side of it The ligamentum transversum spans the cotyloid notch leaving an indentation on the contrast medium below the ligamentum teres

The circular orbicular ligament produces a waist above and below the femoral neck On the under surface of the neck the inferior articular recess is seen medially and the recessus colli is seen laterally above and below the femoral neck The supra articular recess lies above the limbus (LINDBLOM 1952, FISCHER 1952)



Fig 3 Arthrograms in a case of active rheumatoid arthritis Distended capsular recess caudal to the femoral neck associated with nodular filling defects of the hypertrophic synovial membrane

involvement Sosman (1963) also mentioned the capsular contour as seen against the fat pad above the hip, i e between the superior acetabular margin and the greater trochanter, and especially well seen in children the fat and muscle line which is visible inferiorly

Reichmann (1967) stated that it is impossible to identify the upper capsular contour with certainty

It is my belief that in rheumatoid arthritis the distended joint capsule caudal to the joint, produced by the synovial mass lesion in the axial view of the hip



Fig 4 Arthrograms in a further case of active rheumatoid arthritis Distended capsular recess caudal to the femoral neck

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KE [illegible] tional Congress Series No 61, p 301 Excerpta Medica Foundation Amsterdam 1963

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WESTON W J Positive contrast arthrography in rheumatoid arthritis Aust Radiol 12 (1968) 141

Study of the normal arthrogram makes one realise that the assessment of the synovial changes above the hip are not easy The synovial swelling in rheumatoid arthritis produced a mass lesion on the undersurface of the neck Less easily seen is the capsular swelling above the neck, as described by BERENS

The soft tissue mass lesion in the standard a p film can be hidden by the overlying ischio-pubic ramus The overlying bones are cleared in the axial view, in which the caudal soft tissue changes are seen to the best advantage

Arthrogams in two cases with rheumatoid arthritis of the hips are also presented The widest portion of the joint recesses may be seen caudal to the femoral neck Rheumatoid arthritis produces an enlargement of the capsular recesses, as has been demonstrated by arthrography (WESTON 1968) The hypertrophic synovial membrane with its nodular filling defects is demonstrated in the arthrograms (Figs 3 and 4)

No mention has previously been made that the synovial thickening at the hip may be seen as a soft tissue mass on conventional films Is has a well defined caudal margin It is best demonstrated in the axial view where the swelling is cleared from the ischio-pubic ramus (Fig 5)

The soft tissues cephalic to the femoral neck are difficult to assess as there is considerable variation in this area depending on the projection REICHMANN (1967) considers that the appearances vary also with body build and with the state of muscular contraction

## SUMMARY

Well defined synovial mass lesions on the caudal aspect of the femoral neck due to rheumatoid arthritis could be demonstrated in the axial view during conventional radio graphy of the hip

## ZUSAMMENFASSUNG

Synoviallasionen infolge Arthritis deformans am kaudalen Abschnitt des Schenkelhalses wurden in der Axialprojektion wahrend gewohnlicher Radiographie der Hufte gut erkenn bar

## RÉSUMÉ

L incidence axiale dans la radiographie simple de la hanche a permis de mettre en evi dence des lesions bien délimitees de la synoviale, situees sur la face inferieure du col fé moral et dues a la polyarthrite rhumatoide

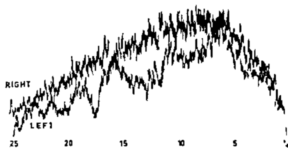



Fig 1 Renography in a patient, aged 48 with uterine carcinoma and pelvic metastases The right renogram is normal The left renogram shows a normal ascending limb but in the excretory or clearing phase the curve has a wavy form

hippuratesodium The animals lay supine and collimators were placed under manual control through the abdominal cavity at the sites of the kidneys. After intravenous injection of 40 μCi of the isotope, the other ureter was clamped as the curve began to slope downwards The right ureter and kidney were left free and served as controls

## Results

A rapid rise in the curve occurred when the clamping was made at the uretero-pelvic junction, and there was a rapid fall when the clamping was released The short wave-form of the curve (Fig 3a) could thus be produced experimentally

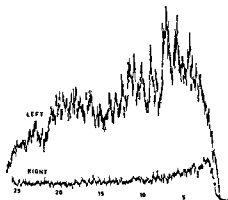



Fig 2 Renography in a patient, aged 44, with uterine carcinoma and pelvic metastases The right renogram indicates poor function of the kidney The curve for the left kidney indicates normal function but the descending limb has a wavy form

FROM THE DEPARTMENTS OF RADIOTHERAPY AND PATHOLOGIC ANATOMY, UNIVERSITY OF TURKU, FINLAND

# EXPERIMENTAL ISOTOPE RENOGRAPHY AS A MEANS OF LOCALIZING URETERIC OBSTRUCTION

by

ILMARI LINDGREN and PEKKA MAKELA

Clinical isotope renography may show a normal curve for one kidney but a more sloping wave form of the descending limb of the other kidney This phenomenon has earlier been described in the literature although its significance may have been neglected (WINTER 1963, ZUM WINKEL 1964) or attributed to arterial hypertension with a renal lesion (WAX et coll 1966) The present authors, having encountered about a dozen patients with a regular short wave form from one kidney, and some kind of ureteric obstruction (Figs 1 and 2), considered that this phenomenon might be due to a relative or valve-like obstruction of the other ureter Experiments were therefore performed in dogs, whose ureters were closed at different levels for varying lengths of time

*Material and Methods* Six adult mongrel dogs weighing 20 to 25 kg were operated on under pentobarbitone anaesthesia (nembutal) and the left ureter was clamped atraumatically for varying lengths of time during renography The occlusions were placed (1) just below the renal pelvis, (2) at the middle of the ureter, and (3) at the ureteric orifice Renography was performed with $^{131}$iodo-

Submitted for publication 25 June 1969 This work was financially supported by the Sigrid Juselius Foundation

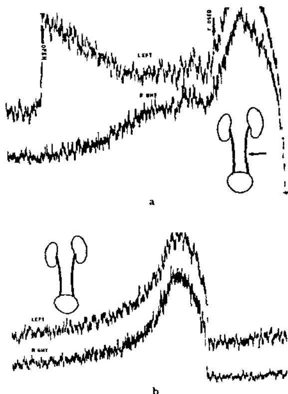



Fig 4 Renography in a dog a) Clamping was made at the middle of the left ureter The curve for the left ureter rises more slowly than in fig 3 b) Both kidneys seem normal after release of clamping

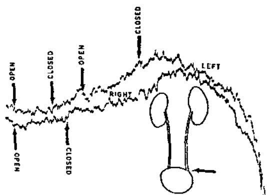



Fig 5 Renography in a dog Clamping was made at the ureteropelvic junction and produced no effect (The paper speed was twice that in the other experiments.)

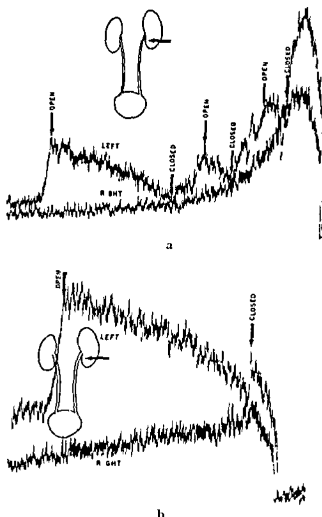



Fig 3 Renography in a dog a) Clamping was made at the ureteropelvic junction b) The curve for the left kidney shows the effect of clamping during a longer period of time (The paper speed was the same as in figs 1 2 and 4 )

When the clamping was maintained for a longer period, with injection of a second isotope dose, the curve continued to rise (Fig 3b) but it fell quickly when the clamping was released Clamping of the middle part of the ureter produced no immediate effect and the wave of the curve was much longer (Fig 4a) A further isotope injection without compression of the ureter caused no such effect (Fig 4b), indicating that no damage had occurred in the kidney which had been affected by ureteric obstruction for 10 minutes Finally, when the ureter was compressed at the ureteropelvic junction, no effect on the shape of the curve could be obtained (Fig 5) The curves of the right kidney were also normal in shape in all the experiments

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN

Vol 10 Fasc. 5 | DIAGNOSIS | 19 0 September

# DOUBLE CONTRAST CYSTOGRAPHY

## A new contrast medium and a simplified technique

by

J TH JENSEN

Double contrast cystography has gradually found its place and justification in diagnostic radiology Certain authors (DIETHELM et coll 1964, JOHANNESSEN 1965), have however, expressed some dissatisfaction with the mucosal coating of the positive contrast media and have pointed out the necessity of refining the technique Several available contrast media have been compared, the best proving to be of approximately the same quality The procedure appears to be time-consuming, and owing to the numerous exposures is expensive and perhaps exposes the gonads to an unnecessarily high radiation dose (BARTLEY & HELANDER 1960 BETOULLIERES et coll 1963, DIETHELM et coll 1964, POCHACZEVSKY & GRABSTALD 1964)

The object of the present study was twofold to find a positive contrast medium adhering better to the mucosa than those previously available and to simplify and, if possible, improve the technique

*Material and methods* The material comprised patients referred for cystography and those with prostatic hypertrophy who were to undergo catheterization or instrumentation of the urinary tract Such patients, elderly, often immobile,

From the Roentgendiagnostic Department (Director Th Rasmussen), Central Hospital, Hjørring Denmark Submitted for publication 17 July 1969

*Comments* zum Winkel (1964) has described the curve from experimental ureteric obstruction corresponding to the present experiment in Fig 3b This figure indicates that a valve-like ureteric obstruction produces a curve of wavy form in the renogram. In clinical renography, this shape of the curve could be due to a stone or any other calcifications in the renal pelvis It might be explained by a rise in pressure in the ureter through the build-up in the volume of urine until it reached a point where it caused a relaxation of the wall and the urine to flow out, with a resultant decrease in the curve of the renogram This may possibly, even in relative stasis, be caused by a tumour, for example

This study furthermore has indicated that it may be possible to localize the height of ureteric obstructions from the renogram curve

## SUMMARY

Experiments in isotope renography were performed in dogs whose ureters were closed at various levels for different lengths of time It seems possible to determine the level of ureteric obstruction clinically from renograms obtained in this manner

## ZUSAMMENFASSUNG

Experimente an Hunden wurden mit Isotopenrenographie während Blockierung der Ureteren an verschiedenen Höhen und zu wechselnden Zeitintervallen vorgenommen Mit solchen Renogrammen scheint es möglich zu sein die Höhe der Ureterobstruction klinisch zu bestimmen

## RÉSUMÉ

Les auteurs ont étudié expérimentalement sur des chiens la néphrographie isotopique après ligature des uretères à différents niveaux et pendant des durées variables Il paraît possible de déterminer d'après le néphrogramme le niveau de l'obstruction urétérale

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and with cystitis, were preferred for assessing the procedure under the *most difficult* conditions, this made the greatest demands on the coating characteristics of the positive contrast medium

Many authors (BARTLEY & HELANDER 1960, BLAKEMORE et coll 1958, DIETHELM et coll 1964, DOYLE 1961, JENSEN & HOLM 1965, JOHANNESSEN 1965, LUKE 1964, POCHACZEVSKY & GRABSTALD 1964, SHAWDON et coll 1965, STAUFFER et coll 1956) have stated that carbon dioxide is the best negative contrast medium, especially as it involves only a slight risk of gas embolism, it was the only negative contrast medium used in the *present study*

The *positive* contrast media employed in the first examinations (BARTLEY & HELANDER 1960, BETOULIERES et coll 1963, *DIETHELM et coll 1964*, DOYLE 1961, *HARBOE KRISTENSEN 1964*, JENSEN & HOLM 1965, JOHANNESSEN 1965, LUKE 1964, MORALES & ROMANUS 1952, POCHACZEVSKY & *GRABSTALD 1964*, SHAWDON et coll 1965 and WALLDEN 1944) were Propyliodone, SH 617 L, Steripaque + Edifas B 50 in a mixture (Edifas is a preparation of *sodium carboxymethyl* cellulose manufactured by ICI), and barium sulphate + *Edifas B* 50 mixed in various ratios and in quantities varying from 5 to 20 ml These will be considered together as the ordinary contrast media

The injection of contrast medium was sometimes preceded by irrigation of the bladder with isotonic glucose or isotonic sodium chloride, and occasionally with undiluted Edifas B 50 The amount of fluid was always 100 ml

The new contrast medium consisted of barium sulphate 500 g, Edifas B 50 24 g and distilled water ad 1 000 g and was dispensed sterilized in tubes of 7 ml The examinations with this contrast medium were not preceded by bladder irrigation

The bladder was emptied by catheterization and sometimes irrigated before an ordinary contrast medium followed by 50 ml carbon dioxide was injected The patient was then rotated once laterally, a further 150 ml carbon dioxide was injected and the patient was rotated again and tilted supine with the head down The following projections were obtained under fluoroscopic control (1) a p supine, (2) patient turned 45° to the right, (3) 45° to the left and (4) to the lateral decubitus position With the patient tilted 15° head down from the supine position, films were exposed (5) a p with the tube tilted 40° cranially and (6) a p with the tube tilted 10° caudally All the films were obtained with a vertical beam This technique will be referred to as the known technique

*The new technique* is a follows The patient voids before the examination, a catheter is passed, the bladder is emptied, and the residual urine is, if necessary measured and 7 ml contrast medium followed by 50 ml carbon dioxide are injected The patient is now rotated laterally, a whole turn with brief stops in the



Fig 1 Male aged 70 years with hypertrophy of the prostate a) Prone position, horizontal beam b) Right decubitus position horizontal beam c) Left decubitus position horizontal beam d) Prone position vertical beam (The illustrations represent examinations with the new contrast medium and technique)

right and left lateral decubitus and prone positions, a further 150 ml carbon dioxide is injected (On rare cases, with a large bladder volume possibly a larger dose) The four films obtained consist of projections with a horizontal beam with the patient prone, in the right and left lateral decubitus positions, and with a vertical beam and the patient prone (cf Fig 1) These projections have been described in the literature (BARTLEY & HELANDER 1960, DOYLE 1961 and 1963, POCHACZEVSKY & GRABSTALD and WALLDEN 1944), but an attempt has been made in the present material to reduce the number of exposures to a minimum without compromising the diagnostic reliability

It may be mentioned that the new contrast medium is also admirably suited for retrograde urethrography

**Table 1**

*Quality of films assessed in relation to the contrast medium and technique Of the 7 patients of the 'medium' group examined by the new technique with the new contrast medium 4 had a good deal of urine in the bladder, and another set of films was incorrectly exposed*

| | Good | Medium | Poor |
|---|---|---|---|
| Ordinary contrast medium Ordinary technique | 5 | 17 | 16 |
| Ordinary contrast medium New technique | 4 | 5 | 0 |
| New contrast medium New technique | 58 | 7 | 0 |

**Table 2**

*Adhesion of contrast media to bladder mucosa assessed in relation to technique Of the 9 patients in the 'medium' group examined by the new technique with new contrast medium, 6 had too much urine in the bladder This also applies to one patient of the 'poor' group examined by the same technique and with the same contrast medium*

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Double contrast cystography was performed in a few instances in continuation of retrograde urethrography with introduction of the contrast medium as well as the $CO_2$ through Knutson's apparatus, i e without catheterization However, this is not recommended as during the long examination the urine flowing into the bladder reduces the quality of the films — further evidence that the quality is better the less urine there is in the bladder, i e the quicker the examination is performed This is one of the reasons why the author has tried to reduce the number of the exposures to a minimum and to use only simple adjustments of the tube

The exposure in the prone position with a horizontal beam is necessary to



Fig 2 Male aged 74 years with carcinoma of the left side of the bladder Right decubitus position horizontal beam The sequelae of transvesical prostatectomy performed 9 years previously (The illustration represents an examination with the new contrast medium and technique )

demonstrate the base of the bladder which is not always defined in the lateral decubitus position (DOYLE 1963)

On occasions the patient was not rotated until all the $CO_2$ had been injected The contrast medium however then became deposited as a girdle around the equator

The material comprised 112 examinations distributed over 105 patients ranging in age from 5 to 87 years with 30 examinations in females and 82 in males Forty-five examinations were in patients under 60 years of age and 67 in patients over 60 47 examinations were performed with the ordinary contrast medium and 65 with the new medium, 38 were by the ordinary technique and 74 by the new technique

In reviewing the films an attempt was made to sort the material by the quality of the exposures and by the coating property of the positive contrast medium This assessment is purely subjective and consequently carries some inaccuracy The results of these assessments are given in Tables 1 and 2

The tabulated results indicate that the new medium and technique produce improved results, including better coating of the bladder wall

## Results

The material was divided into the following three groups

Group I 38 examinations with an ordinary contrast medium and technique.
Group II 9 examinations with an ordinary medium and the new technique
Group III 65 examinations with the new medium and technique

The diagnoses by double contrast cystography and by urography and surgical procedures, i e cystoscopy and operation, were compared Urography was not

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and 23 patients in group III. The hypertrophy had escaped detection at urography in 4 patients but was confirmed by cystoscopy in all but one, and in this latter by examination of the rectum.

Other diagnoses were diverticula of the bladder (in patients with urethral stricture), cystocele (in genital prolapse), and patent internal urethral orifice. This latter finding was made in patients who had undergone operations on the prostate. There was no diagnostic disagreement in any of these patients, but the examinations in group III revealed the changes most distinctly.

## Conclusion

The investigation would appear to confirm the diagnostic value of double contrast cystography in bladder diseases, in particular its superiority to conventional urography. The normal findings in the present material were confirmed by cystoscopy. All tumours were demonstrated, and in 2 patients double contrast cystography proved superior to cystoscopy, in one of these severe bleeding obscured the cystoscopy and in the other the topography of the tumour was better established by double contrast cystography. The extent of bladder invasion by extrinsic malignancy could also be assessed.

Cystoscopy appears to be preferable to double contrast cystography in the diagnosis of cystitis and vesical calculi.

There seems to be good agreement between double contrast cystography and the surgical methods of diagnosis in hypertrophy of the prostate, the former is superior to ordinary urography.

The new contrast medium appears to adhere better to the mucosa and thus produce more acceptable films than the usual media. In addition, the introduction of a new, simplified diagnostic method demands fewer exposures than previously without any reduction in diagnostic reliability.

## SUMMARY

A new contrast medium and a simplified diagnostic technique for do ble cont t cysto-
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## ZUSAMMENFASSUNG

Beschreibung eines neuen Kontrastmittels und einer vereinfachten Prozedur für die Doppelkontrastdarstellung der Harnblase. Die Resultate der neuen Methode werden besprochen und mit denen der alten Methode verglichen. Sie bestätigen den Wert der Doppelkontrastdarstellung der Harnblase besonders bei malignen Erkrankungen, bei denen die Bestimmung der Ausdehnung des Tumors sich besonders nützlich erwies.

performed in a few patients, inter alia, because of elevated serum creatinine Cystoscopy or other surgical procedures were not carried out in 26 patients (11 in group I, 1 in group II and 14 in group III)

No abnormality was detected by double contrast cystography in 31 cases (10 of group I, 2 of group II and 19 of group III) Urography suggested mural infiltration in 1 patient of group III but this was not confirmed by *double contrast* cystography and conventional cystoscopy Cystoscopy revealed trigonal cystitis in another patient of this group

Vesical tumours were demonstrated by double contrast cystography in 18 patients of the three groups consisting of 2 in group I and 3 patients in group II Urography in 3 of these 5 patients has suggested a vesical growth which was subsequently confirmed by cystoscopy Double contrast cystography revealed perivesical malignant infiltration in 2 patients of group II while urography indicated no abnormality, operation revealed carcinoma of the prostate invading the surrounding structures

Four out of 10 vesical growths in group III (cf Fig 2) had escaped detection at urography The tumour in another patient had been masked at cystoscopy by bleeding Cystoscopy in yet another patient had first disclosed one small tumour, double contrast cystography however revealed 3 larger papillomatous growths with marked infiltration of the bladder wall and this was later confirmed by repeat cystcoscopy

Double contrast cystography demonstrated an infiltrating tumour in 1 patient and biopsy indicated carcinoma of the urinary bladder Subsequent operation disclosed marked cystitis, and was confirmed by further biopsy

Three patients of group III had invasion of the bladder, in one from carcinoma of the sigmoid colon and in two from carcinoma of an ovary, the diagnoses were confirmed at operation or autopsy Two of the patients had had a normal bladder at urography, while in the third patient urography had demonstrated compression of the right ureter

Cystitis was disclosed by double contrast cystography in 10 patients, 7 of whom were in group I and 3 in group III, this was confirmed in 9 patients by cystoscopy Cystoscopy also revealed cystitis in 5 patients from other parts of the material, which had not been demonstrated by double contrast cystography

Vesical stones in two patients were confirmed by urography and cystoscopy Double contrast cystography suggested calculi in another patient, these were confirmed by cystoscopy

Hypertrophy of the prostate was diagnosed by double contrast cystography in 35 patients (cf Fig 1), *sometimes co-existing* with trabeculation of the bladder, diverticula and cystitis, and in 4 patients with malignancy (also listed in the group of tumours) The distribution was 10 patients in group I, 2 in group II

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## SUMMARY

A new contrast medium and a simplified diagnostic technique for double contrast cystography are described The results are discussed and compared with those previously obtained The study confirms the value of double contrast cystography in bladder conditions especially in malignancy in which the demonstration of the extent of the growth is valuable

## ZUSAMMENFASSUNG

Beschreibung eines neuen Kontrastmittels und einer vereinfachten Prozedur für die Doppelkontrastdarstellung der Harnblase Die Resultate der neuen Methode werden besprochen und mit denen der alten Methode verglichen Sie bestätigen den Wert der Doppelkontrastdarstellung der Harnblase, besonders bei malignen Erkrankungen, bei denen die Bestimmung der Ausdehnung des Tumors sich besonders nützlich erwies

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## RÉSUMÉ

Presentation d'un nouveau moyen de contraste et d'une technique simplifiee pour la cystographie en double contraste L'auteur examine les resultats et les compare avec ceux de la methode utilisee auparavant Cette etude confirme l'interêt de la cystographie en double contraste dans les affections vesicales, en particulier dans les affections malignes ou il est important de determiner l'etendue de la tumeur

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# NON-FILLING OF THE VENTRICULAR SYSTEM IN ENCEPHALOGRAPHY

by

S HOLM MØLLER

Failure of the ventricles to fill in encephalography has been reported with varying frequency in the literature Special attention has been focused on the extent to which the non-filling may have been due to the presence of an expanding intracranial lesion (Table 1)

LINDGREN (1949) published 152 cases subjected to encephalography, including ten in which the ventricular system failed to fill and in which no tumour was demonstrated In four of the ten cases, cisternal puncture had been performed the day before The clinical signs definitely *indicated* syringomyelia in one, and stenosis of the aqueduct of inflammatory origin in another case, in the remaining four cases, no explanation of the non-filling could be given

DAVIDOFF & DYKE (1951) in a series of 1 056 cases observed non-filling in 7 3 %, and tumours were present in 41 % of these, in encephalography performed under general anaesthesia, non filling occurred in 12 7 % FALK (1953) published 1 841 cases which had undergone encephalography. The ventricles failed to fill in 90 cases (5 %), including 24 (or 26 7 %) with tumours, supratentorial in eight and infratentorial in sixteen of the cases In addition,

Submitted for publication 11 August 1969

**Table 1**

*Survey of previous analyses of non filling of the ventricular system during encephalography*

| Author and year | Number of encephalographies | Non filling | | Expanding intracranial lesion | |
|---|---|---|---|---|---|
| | | Number | Per cent | Number | Per cent |
| LINDGREN (1949) | 152 | 10 | 6 6 | 0 | 0 |
| DAVIDOFF & DYKE (1951) | 1 056 | 78 | 7 3 | 32 | 41 |
| FALK (1953) | 1 841 | 90 | 5 | 24 | 26 7 |
| SCHULEMAN (1953) | 572 | 133 | 23 3 | 6 (13)* | 4 5 (9 7)* |
| SCHEINBERG & YAHR (1955) | 2 641 | 95** | 3 6 | 34 | 48 5 |
| RUGGIERO (1957) | 670 | 47 | 7 | 23 | 48 9 |

* A tumour was diagnosed in six cases and was thought probable in a further seven cases
** Seventy of these were later studied by arteriography, ventriculography or repeat encephalography

stenosis of the aqueduct was present in three cases and confirmed arachnoiditis in four Non-filling was in sixteen cases thought to be due to adhesions and fibrosis caused by preceding meningitis, subarachnoid haemorrhage, or birth trauma

The survey published by SCHULEMAN (1953) covered the 5-year period 1944—1949 A tumour was diagnosed in six and thought probable in a further seven out of 133 cases without ventricular filling SCHEINBERG & YAHR (1955) observed non-filling in 95 out of 2 641 cases examined with encephalography, including 30 in which the air entered the subdural space The examination was extended by arteriography, ventriculography or repeat encephalography in seventy of the ninety-five cases A tumour was disclosed in thirty four (48 5 %) and congenital lesions obstructing the aqueduct in five cases

RUGGIERO (1957) analysed 670 encephalographies from the period 1952—1955 Absence of ventricular filling was recorded in 47 cases (7 %) Of these, twenty-three cases (48 9 %) revealed expanding intracranial lesions supratentorial in six, infratentorial in fourteen and multiple lesions in three cases Stenosis of the aqueduct was present in four cases The air entered the subdural space in two cases Finally, VESTERDAL et coll (1954) had 6 cases of non-filling in a series of 215 encephalographies from a paediatric departement No tumours were observed

Of these authors, LINDGREN, as well as FALK och RUGGIERO, employed the method of LINDGREN (1949, 1950, 1954) SCHEINBERG & YAHR did not give

their technique and the examinations in the other series mentioned were not performed in the form of controlled fractionated encephalography

*Material and Methods* Our series consists of 6 915 encephalographies in the 10 year period 1958—1968, 600 of which were performed under general anaesthesia A relatively large number produced normal findings, i e 2 853 or about 40 % We consider encephalography not only a valuable but also a relatively lenient method of examination and practically all cases with convulsive seizures are subjected to encephalography It may be mentioned however that ventriculography is performed first if the presence of a tumour of the posterior cranial fossa is considered probable During the above mentioned period, ventriculography was carried out in 1 625 cases.

Out of the 6 915 encephalographies absence of ventricular filling was noted in 95 cases (1 4 %) Fractionated encephalography by the method of LINDGREN (1949) is generally employed In nine of the ninety five cases fractionation was not used, however, these were cases of children under 7 years of age The examination is nearly always performed without anaesthesia but general anaesthesia was used in fifteen of the ninety five cases without filling, viz all patients under the age of 15 years and in two aged 17 and 26 years Oxygen was used for the injection

The age distribution of the ninety five cases (Table 2) was fairly even, with a maximum between the ages 40 and 50 years Two patients were under 12 months old but none was over 70 years. The numbers of males and females were almost equal

## Results

Fourteen of the ninety five cases had expanding intracranial lesions (14 7 %), these were supratentorial in four (three extracerebral and one intracerebral), infratentorial in nine (five intracerebellar and four extracerebellar) and in one case consisted of metastases to the cerebrum and cerebellum There were five women between 18 and 64 years of age and nine men aged between 20 and 64 years

Varying amounts of air entered the subdural space in thirteen cases three of these had been subjected to lumbar puncture shortly before and one had undergone craniotomy with inspection of the posterior fossa a week before encephalography Neoplasms were absent in these cases In the remaining sixty eight cases no expanding intracranial lesions were demonstrated Twenty five had had epileptic seizures but check up examinations failed to reveal any cerebral growth

Repeat encephalography was performed in 46 cases Non filling still occurred

**Table 1**

*Survey of previous analyses of non filling of the ventricular system during encephalography*

| Author and year | Number of encephalographies | Non filling | | Expanding intracranial lesion | |
|---|---|---|---|---|---|
| | | Number | Per cent | Number | Per cent |
| Lindgren (1949) | 152 | 10 | 6 6 | 0 | 0 |
| Davidoff & Dyke (1951) | 1 056 | 78 | 7 3 | 32 | 41 |
| Falk (1953) | 1 841 | 90 | 5 | 24 | 26 7 |
| Schuleman (1953) | 572 | 133 | 23 3 | 6 (13)* | 4 5 (9 7)* |
| Scheinberg & Yahr (1955) | 2 641 | 95** | 3 6 | 34 | 48 5 |
| *Ruggiero (1957)* | *670* | *47* | *7* | *23* | *48 9* |

* A tumour was diagnosed in six cases and was thought probable in a further seven cases

** Seventy of these were later studied by arteriography ventriculography or repeat encephalography

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Of these authors, Lindgren, as well as Falk och Ruggiero, employed the method of Lindgren (1949, 1950, 1954) Scheinberg & Yahr did not give

The cisterns were normal in 51 and could not be assessed in 17 of the 68 cases in which no tumour was demonstrated and in which the air did not enter the subdural space Thirteen of these sixty eight cases were not subjected to repeat encephalography, ventriculography or arteriography, as the clinical examination and EEG had revealed no evidence to suggest the presence of an expanding intracranial lesion. Of these thirteen cases the cisterns were normal in eleven and could not be assessed in two cases

Air entered the subdural space in 13 cases. Five of them were subjected to repeat encephalography In one of these the air failed to enter the ventricular system, ventriculography was unsuccessful but biopsy from the cortex revealed sequelae of encephalitis. The films disclosed no abnormalities in three cases and atrophy in one In two cases with epilepsy, ventriculography and carotid arteriography were found to be normal Six of the thirteen cases were not subjected to any of these procedures and a diagnosis of a neoplasm could not be maintained

No severe complications occurred in the ninety five cases examined Convulsive seizures developed in four cases, including one with an acoustic neurinoma. A fall in blood pressure occurred in ten cases, including one with a cerebellar abscess Two patients became restless and confused, one of them had metastases in the cerebrum and cerebellum

## Discussion

ROBERTSON (1957) divided the cases of non filling of the ventricular system into obstructive and non obstructive Obstruction of the foramen of Magendie may be caused by a tumour, a cyst, fibrous tissue or herniation of the cerebellar tonsils He enumerated seven non obstructive causes, including three anomalies of the cisterna magna, viz the tall and the wide cisterna magna and failure of peripheral delimitation of the cisterna magna Two other non-obstructive causes are flow anterior to the cervical spinal cord due to adhesions posteriorly or to too rapid injection of the air, and a narrow vallecula or foramen of Magendie Finally, subdural and epidural injections were also classified as non-obstructive causes ROBERTSON described how the difficulties involved can be overcome by changing the position of the neck and head and directing the air into the foramen of Magendie We were unable to demonstrate that variations in the form and size of the cisterna magna could have been the cause of non filling of the ventricular system in any of the ninety five cases in our series, nor were any cases of herniation of the cerebellar tonsils encountered

LINDGREN (1949, 1951), like ROBERTSON, particularly emphasized the importance of the position of the head for accomplishing filling of the ventricular system, this with reference to the tendency of gases to rise vertically in liquids

**Table 2**

*Age distribution in the ninety-five patients with non filling of the ventricular system*

| Age years | Males | Females |
|---|---|---|
| <1 | 2 | 0 |
| 1—10 | 4 | 5 |
| 11—20 | 4 | 11 |
| 21—30 | 8 | 1 |
| 31—40 | 5 | 8 |
| 41—50 | 10 | 12 |
| 51—60 | 8 | 7 |
| 61—70 | 4 | 6 |
| Total | 45 | 50 |

in 19 cases (41 3 %), including four (21 1 %) in which expanding intracranial lesions were disclosed, in the remaining fifteen cases no tumour could be demonstrated In the four cases with expanding intracranial lesions, the diagnosis was not made at the first examination Repeat encephalography led to satisfactory filling in twenty-six cases and the films revealed no abnormality or atrophy In one case only the fourth ventricle filled due to obstruction of the aqueduct, a finding confirmed by ventriculography The patient in question had had meningitis and was subjected to operation at which a valve was inserted This was the only confirmed case of stenosis of the aqueduct referable to adhesions or fibrosis, although it is possible that such a stenosis may also have been present in some of the other cases

There were nine cases of meningitis or encephalitis In three of these ventriculography had not been performed, and it had been unsuccessful in two cases One case had undergone operation for an encephalocele in the occipital region and one case was considered to have carcinosis of the meninges arising from carcinoma of the cervix uteri, ventriculography was not performed in these two cases

Five of six cases of infantile encephalopathy were subjected to repeat encephalography in which the filling was satisfactory although atrophy was present

In five of the fourteen cases with an expanding intracranial lesion the diagnosis was made on the basis of the appearance of the cisterns, a tumour was suggested in one The cisterns could not be assessed in seven cases and in one the basal cisterns were interpreted as normal, the latter was a case of a tumour in the midline, *viz* an ependymoma of the fourth ventricle The diagnosis was made by arteriography in four cases, in one by ventriculography and in four by arteriography plus ventriculography The diagnoses were confirmed by operation in thirteen cases and by autopsy in one

The cisterns were normal in 51 and could not be assessed in 17 of the 68 cases in which no tumour was demonstrated and in which the air *did not enter the* subdural space Thirteen of these sixty-eight cases were not subjected to repeat encephalography, ventriculography or arteriography, as the clinical examination and EEG had revealed no evidence to suggest the presence of an expanding intracranial lesion Of these *thirteen cases* the cisterns were normal in eleven and could not be assessed in two cases

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LINDGREN (1949, 1954), like ROBERTSON, particularly emphasized the importance of the position of the head for accomplishing filling of the ventricular system, this with reference to the tendency of gases to rise vertically in liquids

LINDGREN also pointed out that to prevent the collapse of cisterns and foramina it is most important that no cerebrospinal fluid is removed before the injection of gas

We had relatively few cases in which the ventricular system failed to fill and among these were also relatively few that had an expanding intracranial lesion FALK (1953) reported non filling in 5 % of his cases and a tumour was present in 26 7 % of these His series consisted of 1 841 encephalographies with a total of 195 cases of tumour The corresponding figures reported by RUGGIERO (1957) were 7 % and 48 9 %, respectively His series consisted of 670 encephalographies, of which also 195 were cases of tumour Non filling in our series occurred in 1 4 %, of which 14 7 % had tumours There were many cases with normal findings in our series Discrepancies in relation to other series are probably due to differences in composition of the series

The distribution between supratentorial and infratentorial tumours in our series is in good agreement with the series of FALK and of RUGGIERO, the infratentorial tumours being about twice as frequent as the supratentorial FALK reported eight supra and sixteen infratentorial tumours while RUGGIERO found six supra- and fourteen infratentorial tumours and three tumours with both supra and infratentorial involvement

There was only one case of confirmed stenosis of the aqueduct in our series while, as already mentioned, there were several cases with this lesion in the other series

On repeat encephalography the ventricular system failed to fill in nineteen of our cases Four of these had tumours, i e 21 1 %, as compared with 14 7 % at the first examination However, as the number of repeat examinations was small, it is not obvious whether any definite difference was obtained In the series described by SCHEINBERG & YAHR (1955), non filling occurred in 24 cases at two or more examinations, tumours were present in about 70 % of these cases

Encephalography performed under anaesthesia results in a higher frequency of non filling In our series, 600 cases were examined under general anaesthesia, non filling occurred in 15 cases, i e in 2 5 % A total of 6 315 cases were investigated without anaesthesia, non filling occurred in 80 cases i e in 1 27 % This difference, which is statistically significant, is in agreement with previously reported results Thus, DAVIDOFF & DYKE (1951) recorded non filling in 12 7 % of their encephalographies performed under anaesthesia as against 7 3 % in their total series It is possible, or perhaps even likely, that this difference could be due to compression of the jugular veins in the cases examined under anaesthesia since the head is suspended during the first films obtained in the sitting position

In our fourteen cases of tumour, the diagnoses were established on assessment

of the cisternal conditions in nearly half the number of cases FALK (1953) diagnosed twenty-one out of twenty four tumours from the appearance of the cisterns

In our ninety five cases of non filling, a neoplasm was present in fourteen cases, stenosis of the aqueduct in one, and the air entered the subdural space in thirteen cases, in the remaining sixty seven cases no definite explanation of the absence of ventricular filling could be given, which represents about 1 % of the whole series FALK in ninety cases of non filling observed a tumour in twenty four, arachnoiditis in four, stenosis of the aqueduct in three and found that obstructive lesions were possibly present in another sixteen cases This leaves forty three cases in which no explanation could be given, i e 2 3 % of the total series RUGGIERO among his forty seven cases of non filling recorded a tumour in twenty three cases, stenosis of the aqueduct in four, and that the air passed subdurally in two cases He thus had eighteen cases in which no explanation of the non filling could be offered, i e 2 7 % in a series of 670 cases The percentage in our series without an adequate explanation of non filling is thus relatively small

It must be emphasized that the present series is most comprehensive and comprises nearly 7 000 encephalographies. When encephalography results in non filling, other things being equal, the chances of the presence of an expanding intracranial lesion are 14 7 %

If the absence of ventricular filling is encountered in radiologic practice, the examiner must first make sure that this could not be due to herniation of the cerebellar tonsils The next step should be, as stressed by LINDGREN (1949, 1950), a detailed study of the cisterns and encephalography should be continued with films obtained with the patient supine and prone in order to achieve satisfactory demonstration of the supratentorial cisterns

## SUMMARY

An analysis of 6 915 cases subjected to encephalography within a 10-year period revealed that the ventricles failed to fill in 95 cases (1 4 %) The causes of non filling of the ventricular system are discussed and the importance of a close examination of both the infra and supratentorial cisterns is emphasized

## ZUSAMMENFASSUNG

Bei Durchsicht eines Materiales von 6 915 Fallen die wahrend einer Periode von 10 Jahren enzephalographisch untersucht wurden, zeigte sich dass in 95 Fallen (1 4 %) keine Fullung der Ventrikel erzielt werden konnte Die moglichen Grunde hierfur werden besprochen und die Wichtigkeit einer grundlichen Untersuchung der infra und supratentoriellen Zisternen wird betont

LINDGREN also pointed out that to prevent the collapse of cisterns and foramina it is most important that no cerebrospinal fluid is removed before the injection of gas

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY II (NEURORADIOLOGY) (DIRECTOR DOCENT B LILIEQUIST), UNIVERSITY OF UMEÅ, SWEDEN

# TOPOMETRIC POSITIONS OF VENOUS ANGLES IN INTRACRANIAL EXPANSIVE LESIONS

by

FRANZ P PROBST

A method to determine the normal positions of the venous angles has previously been described (PROBST 1970) This method was also used in a number of cases with subdural hematomas (19 cases), intracerebral tumours (9 cases) and meningiomas (6 cases) The results obtained will now be considered

The positions of the venous angles in 19 cases of subdural hematomas of varying degree and age (maximum thickness from 0 6 to 5 cm) are represented in Fig 1 Cases 7, 12 and 19 had bilateral subdural hematomas which in Cases 7 and 19 were very large All of the venous angles were situated below the X-axis, ten lying outside the 95 % prediction area but only four outside the 99 % prediction area Cases 1, 3, 11 and 12 were re examined after operation The venous angles of Cases 3 and 11 had returned to what probably was their ordinary positions (3b and 11b) A residual hematoma in Case 1 had prevented the venous angle from regaining its normal site (1b) The hematomas of Case 12 were rather small (maximum thickness 1 7 and 1 0 cm) but postoperatively, at the time of re-examination, a large amount of air was present in the subdural space around the frontal parts of the brain This probably explains the displace-

Submitted for publication 1 April 1969

## RÉSUMÉ

L analyse de 6 915 encephalographies au cours d une période de 10 ans a montré qu il etait impossible de remplir les ventricules dans 95 cas (1,4 %) L auteur etudie les causes de non remplissage du systeme ventriculaire Il insiste sur l importance d un examen attentif des citernes sous et sustentorielles

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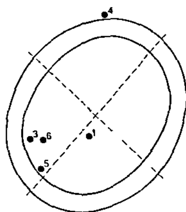



Fig 3 Positions of the venous angles in meningiomas situated in the parasagittal parietal region (Cases 1, 3 6), parieto-temporally (Case 5) frontally (Case 2) and basally (Case 4)

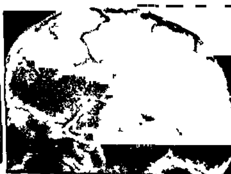
ment of the venous angle (12b) far posteriorly on to the posterior border of the 99 % prediction area Case 19 is illustrated in Fig 2

The positions of the venous angles in 6 cases of meningioma are given in Fig 3 Three of them were situated in the parasagittal parietal region (in Cases 1, 3 and 6), one in the parieto temporal region (in Case 5) and two (in Cases 2 and 4) were situated frontally and basally, respectively Only two angles were outside the 99 % prediction area All of them, however, were located in the segment opposite to the tumour The pre- and postoperative positions of the venous angle in Case 2 are demonstrated in Fig 4

Of the nine cases with apparently well circumscribed tumours (gliomas and



a



b

he tumour
ıal cerebral
b) After

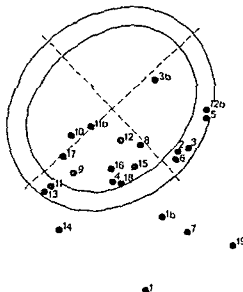
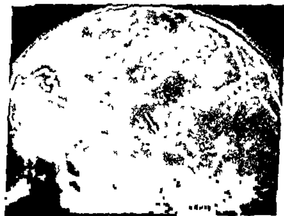



Fig 1 Positions of the venous angles in 19 cases of subdural hematoma Cases 7, 12 and 19 had bilateral hematomas Cases 1, 3, 11 and 12 were re-examined after operation



a b



c

Fig 2 Right carotid angiography in Case 19 a) Frontal view Large bilateral subdural hematomas, maximal thickness right 2 cm, left 1 5 cm The pericallosal arteries not significantly displaced laterally b) Lateral view, arterial phase Hematoma surrounds the frontal lobe and separates the brain surface from the skull c) Lateral view, venous phase The venous angle is depressed and pushed backwards, transtentorial herniation

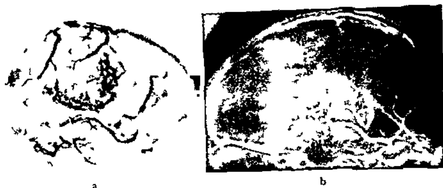



Fig 6 a) Globular metastatic tumour. Lateral ventricle deformed and venous angle depressed (Case 1 in fig 5). b) Basal glioma (Case 2 in fig 5). Venous angle far outside prediction areas.

angle. This agrees well with the clinical experience that temporal tumours, in spite of being of considerable size, often do not displace the angiographic midline structures (especially the pericallosal artery) out of that plane.

In all cases of intracranial tumours (gliomas and meningiomas) the venous angles are situated in that segment of the topometrical figure that is opposite to the growth. Angles lying outside the prediction areas are considered to be displaced with that degree of probability achievable by the method. The others, situated within the prediction area for 95 %, cannot individually be said to be displaced but, because of their position in the segment opposite the tumour, should have moved, at least in part.

## Conclusion

Displacements not exceeding the borders of the 95 % and 99 % prediction areas are not recognizable because of the physiologic distribution of the venous angles within areas measuring as much as 110 and 169 $mm^2$, respectively. The assessment of displacements of the venous angles in the sagittal plane does not therefore achieve the same degree of accuracy as that of displacements across the midline. This metric method nevertheless seems to possess some advantages: it is not marred by subjectivity and permits any venous angle to be placed in relation to the calculated 0 point. The exact direction of deviations as well as of displacements thus becomes evident. This may be a diagnostic clue. The method gives also a definite indication of the tendency and, to some degree, the extent of the displacements in different groups of space-occupying intracranial lesions. The venous angles in uncomplicated subdural hematomas are depressed but return to

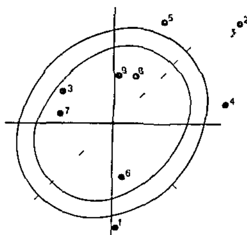



Fig 5 Positions of the venous angles in 9 cases of cerebral tumours (gliomas and one metastatic tumour) Attention may be drawn to the direction and the comparatively slight displacement of the venous angles in the four large temporal tumours (Cases 3 7 8 and 9)

one metastatic tumour), the venous angles of which are plotted in Fig 5, four angles were situated outside the 99 % prediction area, the others lay within the 95 % prediction area All were located in the segment opposite to the tumour Cases 1 and 2 are represented in Fig 6

## Discussion

Unilateral intracranial expansivities usually push the venous angle out of the median sagittal plane, antero posterior compression and shortening of the internal cerebral vein may thus be imitated in the lateral view Displacements of the mid line structures in the median sagittal plane should be especially marked when symmetric pressure forces act on them as they cannot escape laterally The movements (displacements) will then necessarily be confined to the median sagittal plane The extent of the displacement is a result of the strength of the acting force, its direction is the main direction in a parallelogram of strengths An example of this is the marked depression of the venous angles in symmetric bilateral subdural hematomas (Fig 1, Cases 7 and 19)

Subdural hematomas usually lie on the upper lateral surface of the brain The central structures bearing the internal cerebral vein are thus depressed and except in the rare cases of symmetric bilateral hematomas, pushed across the mid line The extent of the depression naturally depends on the size of the hematoma being largest in large bilateral effusions Should an effusion continue basally into the middle cerebral fossa or should there be an associated hematoma within the temporal lobe, it would be expected for the depression tendency to be counteracted This is probably not the case because, as shown in Fig 5 (Cases 3 7, 8, 9) even large temporal tumours often do not cause any significant elevation of the venous

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# LYMPH NODE SCANNING WITH COLLOIDAL RADIOACTIVE GOLD

by

SV E HERTING, P BUCHLER FREDERIKSEN, T JAGT and P JEPPESEN

Major surgery was formerly necessary to reveal pathologic changes in lymph nodes not easily palpated, e g those located in the lesser pelvis and the retroperitoneal space It is, of course, possible to reveal enlargement of lymph nodes by means of various roentgenologic examinations Organs may present deformities or displacements corresponding to the enlarged lymph nodes, or changes in the nape of the mediastinum may be revealed at ordinary chest roentgenography

The introduction of contrast lymphography made it possible to obtain fair detail of the normal or pathologic lymphatic system (WILJASALO 1965, EIKEN 1965) This method has proved of almost revolutionary importance as a diagnostic aid in the detection of malignant disease and not least where examinations of malignant lymphomas are concerned The technique is however somewhat complex and requires skill and special training It can be rather unpleasant for the patient inter alia because it is a fairly lengthy procedure It must also be borne in mind that the examination, although rarely, may have serious side effects even if it is performed in a perfect manner Under such circumstances, a less strenuous method of examination, which could provide information on the condition of the lymph nodes, should be welcome, particularly if reasonably accu

Submitted for publication 27 August 1969

normal positions soon after a successful operation. Intracranial tumours move the venous angles in the direction to be expected from the position of the masses. The degree of displacement depends on the size of the lesion. Temporal growths seem to change the position of the venous angle to a lesser degree and later in development than those situated frontally and parietally.

## SUMMARY

The positions of the venous angles in the median sagittal plane in different expanding intracranial lesions have been determined by the method described in a previous paper. Some preliminary conclusions are drawn.

## ZUSAMMENFASSUNG

Die Lage der Venenwinkel in der Mediansagittalebene wurde in verschiedenen Fällen von intracerebralen expansiven Prozessen mittels der in einem früheren Artikel beschriebenen Methode bestimmt. Einige preliminäre Folgerungen wurden gezogen.

## RÉSUMÉ

La position de l'angle veineux dans le plan sagittal médian a été déterminée au moyen de la méthode décrite dans un article précédent dans différents types de lésion expansive intra crânienne. L'auteur tire des conclusions préliminaires.

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**Table 2**

*Findings in 39 patients in whom contrast lymphography and lymph node scanning gave similar results*

| | Correlation of findings on both sides | | | Contrast lymphography on one side only | | Total |
|---|---|---|---|---|---|---|
| | Both sides pathologic | Both sides non pathologic | One pathologic, one normal side | Pathologic | Normal | |
| Hodgkin's disease | 7 | 3 | 1 | 2 | 2 | 15 |
| Other malignant diseases of the reticuloendothelial system | 6 | 2 | 1 | 3 | — | 12 |
| Carcinomas | 1 | 8 | 2 | 1 | — | 12 |
| Total | 14 | 13 | 4 | 6 | 2 | 39 |

must not exceed 0 5 ml on each side The scanning is carried out 24 hours after the injection, with a Picker Magnascanner having a crystal diameter of 5" and a depth focusing collimator The adjustment of the apparatus is made according to the depth and amount of activity of the para-aortic lymph nodes

It is most important that the patient is ambulatory immediately after the injection of the colloid, to ensure a sufficiently effective distribution of the lymph If the examination is to be repeated later, another interdigital space must be selected, to avoid doubling the radiation dose at the site of injection

*Normal and pathologic scintigrams* The normal scintigram will show a continuous symmetric chain of lymph nodes from the groin to the diaphragm, the liver will also generally be faintly visible

Pathologic changes in the lymph nodes will usually in the scintigram appear as breaks in the lymph chain due to the inability of diseased lymph nodes to accumulate colloid particles The distance between the individual lymph nodes often varies somewhat but this will only on rare occasions give rise to misinterpretations, since the pathologic breaks in the chain are considerably wider than the normal variations Such information about structural changes as is obtainable with isotope lymphography, cannot be obtained with contrast lymphography, because pathologic changes in the lymph nodes will produce a total break in the lymph node chain Large defects in markedly enlarged lymph nodes may however occasionally be visible, depending on the resolution properties of the apparatus employed Furthermore, activities outside the normally located chains may be

**Table 1**

*Classification of the patients into disease groups*

| | With contrast lymphography | Without contrast lymphography | Total |
|---|---|---|---|
| Hodgkin s disease | 17 | 2 | 19 |
| Diseases of the reticuloendothelial system | 14 | 14 | 28 |
| Carcinomas | 16 | 14 | 30 |
| Total | 47 | 30 | 77 |

rate differentiation between pathologic and normal lymph nodes, even without much detail, could be achieved An examination of this nature would be valuable as a screening test as well as for repeat controls in chronic disorders

The lymph nodes of the pelvis and the retroperitoneal space may be demonstrated by means of the lymph node scanning technique This method is not complex and causes only slight discomfort to the patient Radioactive colloidal gold is injected subcutaneously in the feet, and within 24 hours the lymph will carry the colloid to the abdominal lymph nodes Scanning will then reveal in detail the lymph node chains running from the groin to the diaphragm Several authors (DELALOYE & MAGNENAT 1964, JUCKER 1966, KAZEM et coll 1968, SCHENK 1966, VOUTILAINEN & WILJASALO 1965 and ZUM WINKEL & MULLER 1965) have claimed that the method is sufficiently accurate to be used as a screening test and a control for assessing the effects of treatment It has sometimes been possible to obtain information to supplement the findings at contrast lymphography The method is claimed to be completely safe

The object of the present investigation was to test the method and to find out if it will meet the requirements mentioned

*Method* Colloidal radioactive gold, $^{198}$Au, with a particle diameter of 8 to 10 millimicrons is employed It is important that the particle size is just within this order of magnitude, because if particles of a greater diameter are used, e g the usual size of 30 millimicrons, the accumulation in the inguinal lymph nodes will be too great, and the pool of colloid in the abdominal lymph nodes will be inadequate Should the diameter be considerably smaller than 8 to 10 millimicrons, the amount of colloid throughout the chain of lymph nodes would be inadequate

About 100 to 120 microcurie $^{198}$Au, together with 75 units of hyaluronidase and a 0 5 % solution of novocaine without noradrenalin, are injected subcutaneously in the first interdigital space dorsally in the feet The volume injected




F g 2 L mph node scan (a) and contrast lymphog a[ hy (b) n a pat ent th mal gnant lymphogranulomato s n whom pathologic cond t ons corre pond ng to the left lymph node cha n we e demon t ated no t ll ng of the para aort cal lymph nodes Pa holog c lyn ; h nodes w th re es es were p esent on the left s de (b)

*Material* The series comprised 77 cases in which lymph node scanning was carried out over the period fram February 1967 to February 1968 In 47 of these contrast lymphograms were also available which could be compared with the isotope lymphograms In the remaining 30 cases attempts were made to elucidate the results of the examination by means of an assessment of the clinical course results of exploratory laparotomies and autopsy findings

The d stribution of the material into the disease groups malignant lympho granulomatosis other malignant diseases in the reticulo-endothelial system and carcinomas is given in Table 1 The findings at lymph node scanning and at contrast lymphography were compared in the forty seven cases in which both examinations were performed The diagnoses that had primarily been made at the Department of Diagnostic Radiology were employed as a standard for the comparison without retrospective revision of the material or of the scannings

Table 2 represents the results relating to the 39 cases in which the two exami nations were similar Contrast lymphography in eight cases was successful on one side only but the results on the other side agreed well with the findings at scanning

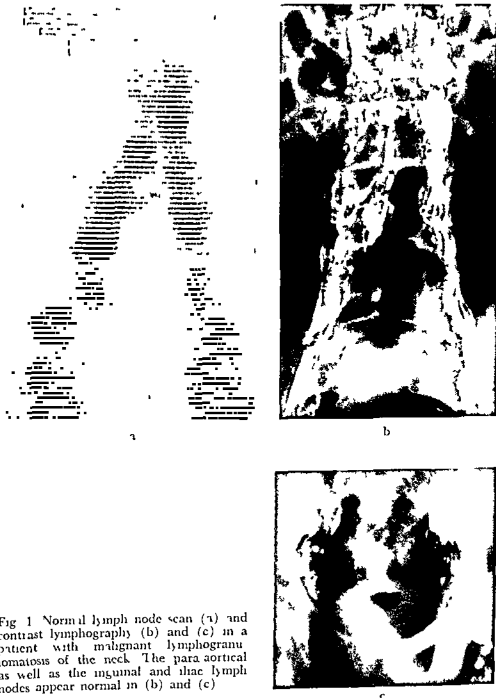



Fig 1 Normal lymph node scan (a) and contrast lymphography (b) and (c) in a patient with malignant lymphogranulomatosis of the neck The para aortical as well as the inguinal and iliac lymph nodes appear normal in (b) and (c)

demonstrated These changes may be caused partly by formation of collaterals and partly because of displacement of the lymph nodes as a consequence of space-occupying processes in adjacent organs




Fig 3 a) Lymph node scan Marked changes with recesses both in the right and the left lymph node chain and enlarged lymph nodes outside the normal location of lymph nodes b) Contrast lymphography Marked changes on both sides

Thus, normal scintigrams were obtained in eleven of the thirty cases, as expected, since there had been no clinical signs of lesions of the abdominal lymph nodes in these cases Pathologic lymphographic scintigrams were obtained in nineteen cases, in the seven cases in which surgery or autopsy was performed, the scintigrams showed pathologic abdominal lymph nodes

The results of the lymphographic scannings were in some of the remaining cases most likely correct when assessed on the basis of clinical considerations This assessment is however of no great value and will not be elaborated upon

## Discussion

The results obtained confirm previous observations made by other workers that contrast lymphography and lymph node scanning are usually in good agreement The present material is limited, and conclusions should therefore be drawn with some reservations Employed as a screening test, lymph node scanning may be considered sufficiently safe and accurate It may in individual

Roentgonologic examination and scanning failed to concur in eight cases Surgery revealed agreement with the findings at scanning in four cases, in two cases the scanning results were not the same as the surgical findings and two cases in which contrast lymphography and scanning did not agree were not verified surgically It must therefore be presumed that the scanning had failed in four cases

False normal lymph node chains were observed in two cases and false pathologic lymph node chains in two cases False normal scintigrams (false negatives) represent the most serious drawback of the method when it is applied for screening purposes since such scintigrams may result in a discontinuance of the examination The two false pathologic findings did not essentially invalidate the examination from a screening point of view False positive scintigrams will only cause further examinations to be carried out, i e contrast lymphography

The misinterpretations of our scintigrams were due partly to the fact that the scanning was carried out in one plane only — hence no displacement of the lymph node chains perpendicular to the scanning plane could be demonstrated — and partly to an unusually wide normal variation in the distance between the individual lymph nodes

The evaluations of the lymph node scintigrams in the thirty cases in which contrast lymphography had not been performed are presented below comprising nineteen pathologic and eleven non pathologic scintigrams

Pathologic scintigrams were obtained in 19 cases according to the following

| | |
|---|---|
| Cavography showed deformity corresponding to lymph nodes | 1 |
| Clinically localized reticulum cell sarcoma corresponding to one inguinal region and normal scintigram on the other side | 2 |
| Generalized reticulum cell sarcoma with universal gland swelling | 5 |
| Operation disclosed pathologic glands on both sides | 2 |
| Autopsy showed pathologic glands on both sides | 5 |
| No check up, apart from the clinical examination | 4 |

Non pathologic scintigrams were registered for 11 cases as follows

| | |
|---|---|
| Malignant disease not demonstrated | 1 |
| Cerebral tumour, other diseases not known | 1 |
| Lung cancer liver metastases | 1 |
| Clinically localized disease of the neck (Brill Symmer s disease and transitional carcinoma) | 3 |
| Minor abdominal surgery (appendectomy) no pathologic glands were observed | 1 |
| No clinical signs of pathologic lymph nodes and no decisive follow up result | 4 |

ditions to any degree of accuracy Other authors have suggested that about two-thirds of the isotope disappear within the first 24 hours

We measured the volume of the isotope and examined its distribution by scanning in seven cases It was found that the volume of isotope retained varied from 29 to 98 % of the volume injected By scanning over the dorsum of the foot, the isotope proved to be located in the subcutis in areas ranging from 1 5 to 14 $cm^3$ in size From these values the most frequent radiation dose was estimated to be 700 to 2 000 rad, and sometimes about 3 000 rad, when the entire volume of isotope remained at the site of injection These radiation doses will usually cause no damage

Radiation necroses were not observed in the present material but this complication may be within the range of possibilities It cannot be precluded, from a theoretical point of view, that radiation induced malignant tumours might occur many years later, although presumably this will happen only infrequently As the method is intended for use as a safe screening test, it must be admitted that in this respect it does not fully comply with the requirements

As regards irradiation of the remaining parts of the body, it has been reported in the literature that the dose to the liver and the gonads ranges between 0 5 and 1 rad from one examination

The method relies upon the fact that lymph nodes accumulate colloids of a certain dimension, and it should be possible to use the technique also with other colloids This has been attempted (SCHENK 1966) but the most favourable result from a diagnostic point of view has been obtained with the gold colloid Nevertheless, the high radiation dose to the foot makes it necessary to seek other isotopes of colloid compounds, preferably short lived isotopes emitting only gamma rays, by means of which the diagnostic outcome can at the same time be improved

However, as the method is intended for use in cases of malignant disease, in which a deficient diagnosis may present a considerably higher risk than the risk run by the exposure of the patient to the lymph node scanning now described, it may yet be recommended in spite of the relatively high radiation dose to the interdigital space of the foot

## SUMMARY

Isotope lymphography was carried out over a period of one year in 77 patients suffering from malignant disease Contrast lymphography was performed in connection with the scanning in 47 of the patients, and the results were used as a standard for comparison In the remaining 30 patients the surgical and clinical findings were used as a basis for the evaluation The good agreement obtained suggests that lymph node scanning is sufficiently safe and accurate as a screening test and for control examinations

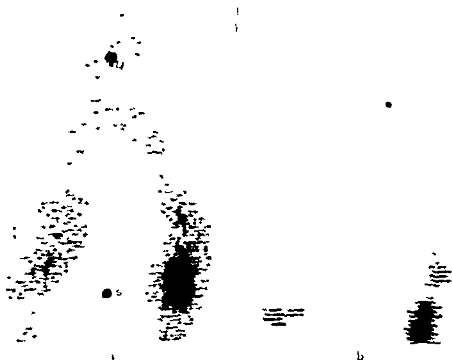



Fig. 1. Lymph node scans in a patient with malignant lymphogranulomatosis. Attempts at contrast lymphography failed presumably because this had been carried out two years previously. a) The patient had no symptoms at the time of scanning; slight changes on both sides. b) Nine months later the patient had raised temperature, itching of the skin and an increased tendency to perspiration.

cases provide information supplementing the results obtained with contrast lymphography, and it is well suited for follow-up examinations on an out-patient basis.

The isotope lymphogram does not reveal the structures of the individual lymph nodes, which is an important feature of the diagnostic merits of contrast lymphography. For both examination methods applies that the pathologic findings are not specific of malignant disorders, and this may give rise to some difficulties as far as the differential diagnosis is concerned.

As regards side effects, a prolonged bluish discoloration of the skin on the dorsum of the foot, around the site of the injection, was observed in some cases. Oedema occurred in a few cases at the sites of injection and lasted for a few days but it then disappeared rapidly and caused no pain or other discomfort.

It was difficult to assess the radiation dose to the site of injection, because the radioactive substance disappears from the feet at a somewhat varying rate. To this should be added that it is difficult to determine the radiation geometric con-

FROM THE ROENTGEN DEPARTMENTS OF ST ERIKS SJUKHUS (DIRECTOR S E SJÖGREN) AND SERAFIMERLASARETTET (DIRECTOR PROF ERIK LINDGREN), STOCKHOLM, SWEDEN

# VENOUS COMMUNICATIONS OF THE ADRENAL GLANDS

## Anatomic and circulatory studies

by

C G MIKAELSSON

The anatomy of the efferent vein from the left adrenal gland, in the series of epinephro-phlebographies described earlier (MIKAELSSON 1969), was the same in all the twenty-three glands examined by the author's modified technique In every instance there was one draining vein of normal anatomic appearance from each adrenal gland and no other drainage from the intraglandular veins could be observed Attempts at catheterization of the right adrenal vein in 51 instances were successful in only 36, and as catheterization was not facilitated towards the end of the series, despite increasing experience, it seemed likely that some obstruction of anatomic nature to the catheterizations might be present The films from the phlebographic series were also found to be suitable for a study of the direction of flow after injection of contrast medium into the veins of the adrenal glands and into extraglandular vessels.

This work was financially supported by Grant B69 61P 2601-01 from the Swedish Medical Research Council. Submitted for publication 24 June 1969

## ZUSAMMENFASSUNG

*Isotopenlymphographie* wurde wahrend eines Jahres in 77 Patienten mit malignen Krankheiten angewandt In 47 von diesen Patienten wurde Kontrastmittellymphographie gleichzeitig ausgefuhrt und die Resultate wurden als Vergleichsstandard benutzt In den ubrigen 30 Patienten dienten die chirurgischen und klinischen Befunde als Grund fur die Beurteilung *Die* gute Übereinstimmung der Resultate deutet darauf hin dass Isotopenlymphographie eine genugend sichere und zuverlassliche Methode ist um bei screening und Kontrolluntersuchungen verwendet zu werden

## RÉSUMÉ

Pendant une periode d un an les auteurs ont fait des lymphographies isotopiques chez 77 malades atteints d affection maligne Les resultats de la lymphographie isotopique ont ete compares a ceux de la lymphographie par moyen de contraste chez 47 de ces malades et *compares aux constatations chirurgicales et cliniques chez les 30 autres malades* La bonne concordance obtenue fait penser que la scintigraphie des ganglions lymphatiques est une methode sans danger et suffisamment precise comme test de depistage et comme examen de controle

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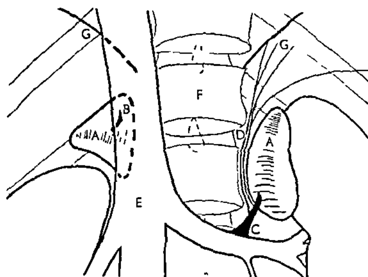



Fig 1 Position of adrenal glands in relation to kidneys and spinal column and the venous drainage to the vena cava and left renal vein A = adrenal glands with dorsal crest B = right adrenal vein C = left adrenal vein D = left inferior phrenic vein E = vena cava with renal veins F = twelfth thoracic vertebra G = diaphragm

## Earlier investigations

The appearances of the adrenal glands and their vasculature according to earlier authors will be discussed first

The left gland is more elongated than the right, and its thickest portion — the head according to DOBBIE & SYMINGTON (1966) — is directed inferiorly while the body and tail point in a craniolateral direction The hilum with the large efferent vein lie on the ventral surface of the head Along the dorsal surface, a ridge-like elevation between the caput and cauda, the crest, slopes laterally, and a deep groove is formed between the ridge and the lateral portion of the gland A shallower groove on the ventral surface corresponds to the crest on the other side (DOBBIE & SYMINGTON 1966, MERKLIN & EGER 1961) (Figs 1 and 2)

The right gland is more or less triangular Its head is located in the medial portion, the ventral surface of which together with the hilum and efferent vein lie immediately adjacent to the right dorsal part of the vena cava wall A crest runs on the dorsal surface between the head and tail, and the latter part of the gland is directed towards the right (ANSON et coll 1947, GAGNON 1956, DOBBIE & SYMINGTON 1966)

Each gland consists in reality of two distinct organs — the cortex, a derivative of the coelomic epithelium near the cranial pole of the mesonephros, and the

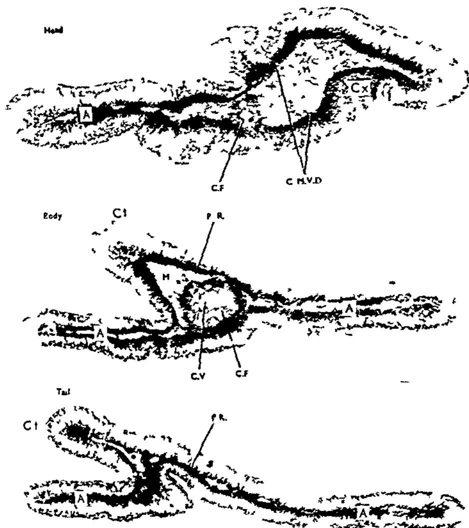



Fig. 2 Sections through the head (upper view) body (middle view) and tail (lower view) of the left adrenal gland ×6. The dorsal surface with the crest faces upwards. A = alae with alar raphe. Cx = cortex. C.F. = cortical cuff. P.R. plexus reticularis. C.M.V.D. = cortico-medullary vascular dam. Ct = crest. C.V. = central vein. M medulla. (Slightly modified from DOBBIE & SYMINGTON 1966.)

medulla which develops from the sympathetic trunk. The two organs unite during embryonic development, the cortex moving downwards and the medulla upwards to penetrate into the cortex (BROMAN 1927, MERKLIN & MICHELS 1958). The medulla is located mainly in the central area of the head segment.

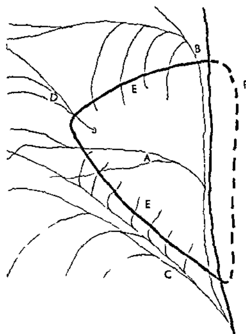



*Fig 3* Right adrenal gland with superficial veins (A) communicating with right inferior phrenic vein (B) C = renal capsule veins D = emissary vein E = concomitant veins F = vena cava

and takes up approximately one-quarter of its mass while the tail is composed wholly of cortex, as are also the wings of the glands, the so-called alae (DOBBIE & SYMINGTON 1966) (Fig 2)

*Arteries* The highly diversified blood supply of the adrenal glands is considered to be explained by the embryonic development These arteries are usually divided into three main groups according to the following vessels of origin (1) the inferior phrenic arteries and celiac artery, (2) the aorta, and (3) the renal and gonad arteries Branches from these stems divide in the fatty capsule of the adrenal glands into a large number of fine vessels that enter the gland and mainly supply its subcapsular capillary network A few arteries penetrate more deeply into the cortex and medulla (GERARD 1913, ANSON et coll 1947, BUSCH 1955, GAGNON 1957, MERKLIN & MICHELS 1958, MERKLIN 1962, DOBBIE & SYMINGTON 1966, LINDVALL & SLEZAK 1969, and others)

*Peripheral veins* A large number of small concomitant veins more or less follow the arteries and like them may be divided into three groups (GAGNON 1956, BOBROVA 1965, SHDANOW & SSAPIN 1968, and others) (1) the cranial group running to the inferior phrenic vein, which usually empties into the vena cava, (2) the middle group, which connects up with (3) the inferior group The latter vessels are closely associated with their corresponding arteries, but there are more

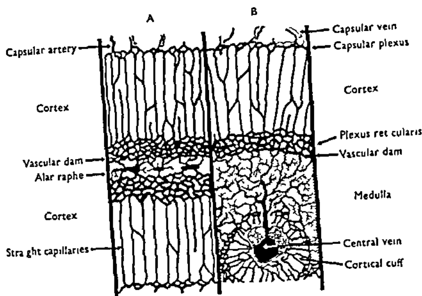



Fig 4 Transverse section showing the vascular system of an adrenal gland A part of the gland with medulla lacking B medulla present (From DOBBIE & SYMINGTON 1966 )

veins than arteries These veins run to vessels in the renal capsule, or directly to the vena cava

Other veins of varying size run on the surface of the adrenal glands, and either anastomose with veins in the diaphragm or renal capsule (BOBROVA 1965), or are in direct communication with the intraglandular, central adrenal veins, they are then known as emissary veins (KUTSCHERA AICHBERGEN 1922, MERKLIN & EGER 1961, DOBBIE & SYMINGTON 1966, and others) (Fig 3) Communications with the portal system, via the pancreas on the left side and the hepatic capsule on the right, have been reported (KUTSCHERA AICHBERGEN 1922, BUSCH 1954/55, and others), as well as anastomotic connections with the vena azygos and vena hemiazygos (GAGNON 1956)

*Capillaries* The subcapsular capillary network on the surface of the adrenal glands continues into the cortex, some of the capillaries penetrating directly downwards through the two upper cortical zones to form a new, richly diversified network in the reticular zone (MERKLIN 1962, and others) (Fig 4) This network is sharply demarcated on the inner side of the cortex, in an arrangement called the vascular dam (VELICAN 1947)



Fig 5 Openings of right and left adrenal veins into the vena cava and left renal vein Intra glandular veins (⟶), superficial veins ( ↦ ), and emissary vein (⤀) anastomosing with renal capsule and phrenic veins



Fig 6 A large liver vein between the right adrenal and renal veins The left adrenal vein opens into the dorsal cranial shank of a peri aortal ring Central adrenal veins (→), inferior phrenic veins ( ↦ ) emissary vein (⤀), cut off hepatic vein (⤀)

*Central veins* From the inner network of capillaries in the cortex, small veins converge in the alae within the so-called alar raphe and unite into larger and larger vessels (Fig 4) Many of the larger veins pass through the medulla and are usually surrounded by an invaginated cuff of cortical tissue, their adventitia consisting of longitudinal muscle fibres Other veins in the alar raphe and medulla have no cortical cuff and consist only of a single layer of endothelium These open into the muscular vessels, either between the bundles of muscle fibres or through slits in the bundles (MARESCH 1921, DOBBIE & SYMINGTON 1966, and others) Near the hilum, the muscular elements of the central veins envelop the circumference and further towards the periphery thin out into scattered muscle bundles that often protrude into the lumina of the veins They are mainly located on the medulla facing segment of the veins (DOBBIE & SYMINGTON 1966) Some muscle fibres extend from the venous walls out into the parenchyma of the gland (MARESCH 1921, and others) Arcade like anastomoses which, according to SHDANOW & SSAPIN (1968) increase in numbers in connection with hypertension, are found between the peripheral ramifications of the central venous system

*Efferent veins* On the left side, the veins unite into one vein stem or a few vessels that rise in the crest in the tail portion of the gland and run obliquely through it (DOBBIE & SYMINGTON 1966) They pass through the hilum as one vein After having received the inferior phrenic vein from the medial side, the vein runs inferiorly and slightly medially for a distance of 2 to 4 cm towards the renal vein, usually entering it about 2 to 5 cm from the vena cava (GAGNON 1956, and others) In the right adrenal gland, several stems usually converge to unite in the hilum into an efferent vein that is very short (1 to 5 mm) This vein runs medially, often also cranially, to the right dorsal portion of the vena cava wall (ANSON et coll 1947, GAGNON 1956, and others)

Opinions differ however regarding possible anatomic variations in the draining veins. ANSON et coll (1947), in 425 autopsies, examined the entire retroperitoneal venous system including the adrenal veins. GAGNON (1956) carried out 116 necropsies, paying special attention to the adrenal veins and examining 100 on each side The veins had not been prepared, and he made the reservation that small veins could have been missed HEINIVAARA (1953/54) studied the adrenal veins in 29 autopsies, CLARK (1958/59) reported on 16 necropsies and JOHNSTONE (1957) made a similar study in 10 instances after intravenous injection of latex He also measured the width of the veins but did not mention how this was done

As regards the left side, CLARK noted in five instances that in addition to the ordinary vein from the hilum a wide vein ran between the dorsal surface of the adrenal gland and the renal vein All the other authors reported that there was



Fig 5 Openings of right and left adrenal veins into the vena cava and left renal vein Intra glandular veins (⟶), superficial veins (↦), and emissary vein (⤅) anastomosing with renal capsule and phrenic veins



Fig 6 A large liver vein between the right adrenal and renal veins The left adrenal vein opens into the dorsal cranial shank of a peri aortal ring Central adrenal veins (→), inferior phrenic veins (↦), emissary vein (⤅), cut off hepatic vein (⤅)

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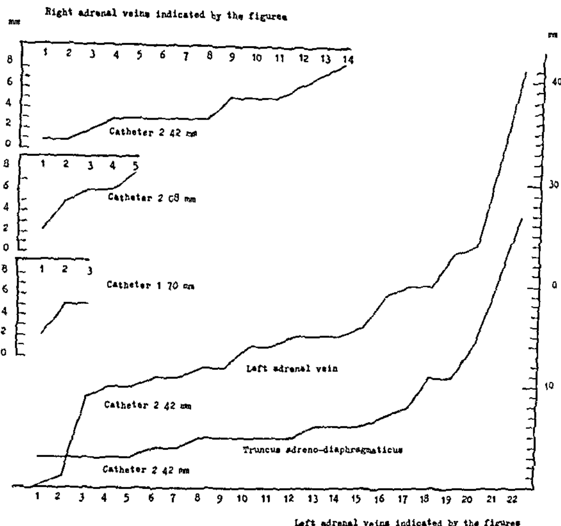



Fig 7 Diagram showing how the adrenal veins were catheterized Each case that was *catheterized is marked* on the abscissas and the catheterizable lengths of the veins on the *ordinates measured in mm The whole length* of the truncus adreno diaphragmaticus could always be catheterized and is shown independently of the catheter length of the left adrenal vein proper

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As regards the right side, the first three investigators stated that a single vein always ran between the adrenal gland and the vena cava CLARK's and JOHNSTONE's observations differed CLARK observed in seven instances another large vein running from the head of the gland to the vena cava, and JOHNSTONE found that in five instances the efferent vein opened into a liver vein and in one instance into a rudimentary vena cava on the right side located between the renal vein and



Fig 8 Two extraglandular veins running to the right adrenal vein and a vein in the ventral sulcus of the left adrenal gland (arrows) running to the efferent vein in the hilum No other connections between intra and extraglandular vessels are visible

the atrium The vena cava was of normal size on the left side In two instances the adrenal vein was divided into two or three vessels respectively, opening into the vena cava Only two veins emptied single into the vena cava, and one of them was only 2 mm wide In the case, in which three adrenal veins were present, the largest was 2 5 mm wide In the other cases there was always a vein measuring at least 3 mm in width that ran from each adrenal gland

## Present investigation

*Material* A series of 22 necropsy specimens were studied These were taken from 11 female and 11 male bodies, from patients over 50 years of age who had died of cerebral or cardiac diseases The anatomic studies were mainly carried out to investigate the direct venous communications between the large central veins of the adrenal glands and the vena cava together with its tributaries

Films from the phlebographies previously carried out by the writer in 25 adrenal glands on the right side and 36 on the left side were also studied These examinations were performed with a film changer, in patients with essential or renal hypertension, and there were no complications or demonstrable tumours The films were obtained by serial exposures at intervals of 0 67 seconds and were studied from the aspects of the anatomy and blood flow after injection of contrast

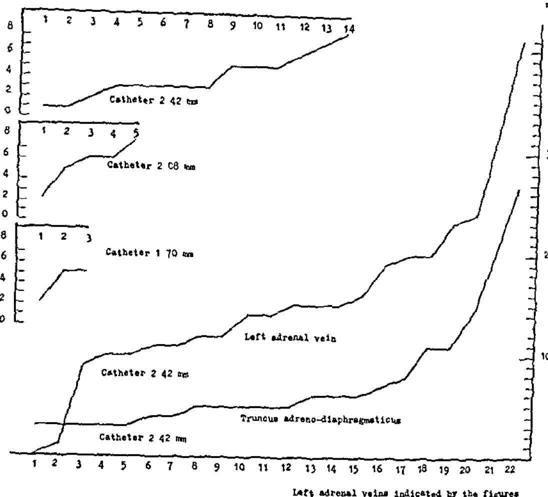



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Fig 9 Transverse section of the vena cava (A), with the right adrenal vein marked in black Its outlet was always located within the marked area on a level with the twelfth thoracic vertebra (C) The aorta is indicated by B

medium within anastomosing extraglandular veins in close proximity to the adrenal glands before their communications with more distant vessels

T[illegible] tions was used
Th[illegible] ium by a modification of the method for microangiography described by IVEMARK et coll (1967) With all organs still in position, a suspension of barium sulphate, in which one part by weight of Mixobar (Kistner) had been mixed with three parts of water, was infused into the upper portion of the vena cava through the right atrium from a container placed about 60 cm above the body Owing to leakage through the vena azygos and other paravertebral veins the mediastinum had to be ligated in advance directly caudal to the hilum of the lung as well as in the cranial portion of the mediastinum Blood and coagula were removed as far as possible from the venous system by palpation, in most cases the inferior part of the vena cava was compressed by pressure from above Infusion was continued for two hours In the last fourteen necropsies, a procedure similar to LINDBOM's (1950) method was used in addition to the infusing process The contrast medium was withdrawn from the large veins, a new barium suspension containing 20 g gum arabic and 30 g gelatine per 700 g suspension was added, and this was allowed to solidify for about 30 minutes The intestine was then removed, and the other abdominal organs and retroperitoneal tissues together with the muscles and anterior portion of the vertebral bodies were taken out in one block and fixed in 10 % formalin for one week This gave specimens that were suitable for dissection in association with roentgen examinations The liver, stomach, pancreas and spleen, except for the parts adjacent to the adrenal glands were removed in each preparation before the studies were begun

The preparations were roentgenographed at several stages of the work and between the examinations organs were removed approximately in the following order (1) spinal column, (2) skeletal muscles, (3) remaining parts of the stomach, pancreas and spleen, (4) extracapsular tissue dorsal to the adrenal




Fig 10 A small hepatic vein and a right adrenal vein opening laterally into the vena cava through a 4 mm long common stem The liver vein is cut off at the liver capsule (arrow) a) A p view b) Axial view Dorsal surface downwards

glands and kidneys, (5) remaining parts of the liver parenchyma, (6) liver capsule, (7) extracapsular tissue ventral to the adrenal glands and kidneys, and (8) capsules of the adrenal glands, subcapsular veins, and kidneys

In the early stages of the dissections the specimens were roentgenographed in a water bath The films were obtained at a focal distance of 90 cm Non-screen industrial film (CEA) without a grid was exposed with the small focal spot, using 50 to 40 kV and 800 to 100 mAs At least three views were obtained at each roentgen examination, with adjustement for an increased stereoscopic effect with the tube angled 30° and 15° from the right and 15° from the foot end The diameters of small veins were measured on the roentgen films with a micrometer screw and with a magnification of $\times$ 20 After removal of the contrast mass, the width of the adrenal veins was investigated by introducing polythene catheters of sizes P E 240, 205 or 190 and with an outer diameter of 2 42, 2 08 or 1 70 mm A note was made of the largest catheter that could be used and of how far it could be pushed in, measuring from the vena cava or the opening of the phrenic vein into the left adrenal vein

The inner vena cava wall and renal veins were also investigated for possible outlets of undetected vessels (which were never found)

Before the barium infusions, trials had been made in about 10 necropsies, with infusion of polymerizing plastic, Quick 33, which sets in 20 to 30 minutes, depending on the amount of hardener added As the venous filling obtained was not satisfactory, these experiments were not included in the present series

a b

Fig 11 Epinephro phlebography The veins in the right adrenal are filled at the same time as those in a small liver lobe Numerous anastomoses to other liver veins are visible as usual in the liver lobe a) A p view A large amount of contrast medium is concentrated to the liver lobe b) Oblique view The adrenal veins filled well after changing the position of the catheter



Fig 12 The venous system of both adrenal glands is filled out to the outermost parts of the alar raphe The darker strip between the hilum in the head portion and the tail is the crest on the dorsal aspect

*Technical considerations* A large number of veins of all sizes down to a diameter of 0 03 mm were well filled at all levels of the preparations, despite the presence of coagula in the large and medium sized vessels and notwithstanding that in the first eight cases the contrast medium had been partially emptied from these vessels when the specimens were removed The veins could nevertheless be assessed satisfactorily, as a sufficient amount of barium had become attached to their walls In the peripheral veins, the barium particles had become packed into a powdery mass owing to sedimentation, while the fluid in the suspension had passed on This had already been observed during the infusion, when the peritoneal fluid gradually increased

The roentgen examinations were a valuable aid during the dissection work, among other things because they gave information on whether vessels that had been dissected out continued within the adrenal glands or not Because of their white colour, the contrast filled vessels were also easily distinguished in the necropsy studies

Polymerizing plastic as a filling for the veins proved to have disadvantages and could not be used in the present investigation Abrupt blocks and breaks in the continuity often occurred, even in relatively large vessels Because of surface tension, it is probably difficult for a plastic material, which is insoluble in blood, to push past the clots that commonly occur in dorsally located veins and tend to occlude them during infusion

## Results

*Position of the adrenal glands* The left gland always lay near the upper medial portion of the kidney, close to its ventral tangent, and the head of the gland usually extended down to the cranial part of the renal hilum The right gland was always located beside the liver and the vena cava, at the level of the twelfth thoracic to first lumbar vertebrae, irrespective of the kidney's position Similar conditions have been reported by LINDVALL & SLEZAK (1969) In fifteen instances, the right adrenal glands were triangular, with sides of approximately equal lengths, but in seven the cranial side was short and the crest began near the inferior corner of the gland

*Efferent veins* In all instances, only one efferent vein from the central venous system of each gland was observed The left adrenal vein always opened into the left renal vein at a point 13 to 46 mm from the vena cava (Figs 5 and 6) The inferior phrenic vein opened into the renal vein in one instance and into the adrenal vein in all the others All adrenal veins on the left side could be catheterized with a 2 42 mm catheter for a distance of 3 to 27 mm past the openings of the phrenic vein or of any other tributaries present The truncus adreno-diaphragmaticus was 1 to 31 mm long (Fig 7)

a b

*Fig 11* Epinephro phlebography *The veins in the right adrenal are filled at the same time* as those in a small liver lobe Numerous anastomoses to other liver veins are visible as usual in *the liver lobe* a) *A p view A large amount of contrast medium is concentrated to the liver* lobe b) Oblique view The adrenal veins filled well after changing the position of the *catheter*



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Fig 14 Concomitant veins around both adrenal glands. Central veins around an adenoma (arrow) (Vasa vasorum aortae are also visible)

forming a common stem with a liver vein, the outlet was located ventrally within that sector A study of the phlebographic findings in previous publications revealed that the catheterized adrenal veins, two of which had common stems with a liver vein, always had their outlets within an area extending 1 cm cranial to, and 1 5 cm inferior to the twelfth rib (MIKAELSSON 1969) (Fig 11)

The 2 42 mm catheter could on the right side be inserted for a distance of 1 to 8 mm in fourteen veins, while eight veins were too narrow to admit it A 2 08 mm catheter passed in for 2 to 8 mm in five vessels, and in the other three only a 1 70 mm catheter could be pushed in for 2 to 5 mm (Fig 7)



Fig 15 Adenoma of the right adrenal gland in fig 14

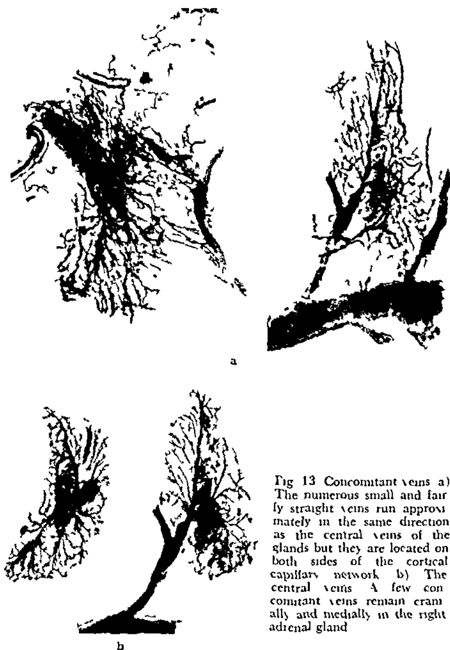



Fig 13 Concomitant veins a) The numerous small and fairly straight veins run approximately in the same direction as the central veins of the glands but they are located on both sides of the cortical capillary network b) The central veins A few concomitant veins remain cranially and medially in the right adrenal gland

On the right side, the efferent vein ran directly to the vena cava in 20 out of 22 necropsies (Figs 5, 6 and 8) In two instances, the right adrenal vein and a small hepatic vein had a common stem outside the adrenal and hepatic capsules for a distance of 4 mm and 1 mm respectively before reaching the vena cava (Figs 10, 18 and 20) All the efferent veins from the right adrenal glands opened 19 to 62 mm cranial to the right renal vein into the right dorsal quadrant of the vena cava wall (Figs 9 and 10) When the venous outflow took place through a vessel

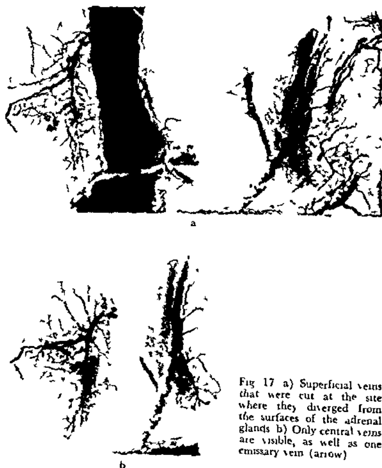



Fig 17 a) Superficial veins that were cut at the site where they diverged from the surfaces of the adrenal glands b) Only central veins are visible, as well as one emissary vein (arrow)

In addition to the concomitant veins, a number of small and relatively large veins with a winding irregular course over the surface of the glands, and often located between the capsule and cortex, also filled with contrast medium They often joined veins in the renal capsule, but sometimes connected up with central vein branches of the adrenal gland, they then had the appearance of emissary veins (Figs 5, 6 and 17)

As has also been reported by SHDANOW & SSAPIN (1968) superficial veins were observed at the bottom of sulci in eleven glands, in most instances in the ventral groove of the left gland They had extraglandular tributaries, and in six instances had direct communications with the efferent vein in or slightly before the opening into the hilum (Figs 8, 18 and 19)



Fig 16 A large vein in the dorsal groove lateral to the crest in the left adrenal gland (arrow) Part of the vein has been removed Concomitant veins are seen between the gland and the kidney

*Central veins* A large number of the central veins, down to a diameter of 0 03 mm, filled with contrast medium In six glands however the filling was incomplete, and seven had ruptured centrally The veins in the others could be followed to a point 1 to 2 mm from the edges of the glands This corresponds to the inner surface of the cortex at its transition between the ventral and dorsal surfaces of the gland (Figs 8, 10, 12, 13, 16 and 19) Anastomoses of the type described by SHDANOW & SSAPIN (1968) were seen in thirteen glands, with one to four in each

*Peripheral veins* A large number of small venae comitantes outside the adrenal glands always filled with contrast medium They were all of relatively the same diameter, about 0 1 mm, and were either comparatively straight, or arched They radiated out from the glands in the same direction as the large branches of the central veins, although most of them were not continuous with those vessels In the head of the left gland for instance they ran in an obliquely caudal direction, while in the body and tail they took an increasingly oblique, cranial course The arrangement was more or less similar in the right gland Some of them were directly continuous with small central veins, but most of them began at the surface of the gland (Figs 13, 14, 16 and 18)

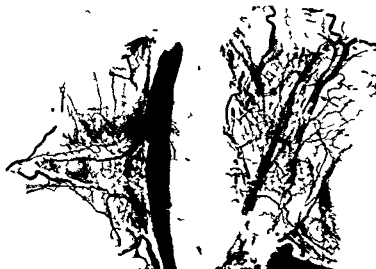


Fig. 18. A right adrenal vein with a 1 mm long stem in common with a small hepatic vein. A large vein in the dorsal sulcus of the left gland (→). Several ventral capsule veins mostly in the ventral sulcus run to the efferent vein (↦).



Fig. 19. Most extraglandular vessels are removed. Small ruptures in both glands. Same case as in Fig. 18.

*Studies of the blood flow at phlebography* These studies included the extra glandular veins before their anastomosis with large vessels outside the glands, in other words within a distance of about 1 cm from the glands The flow of contrast medium was studied after injection Only veins that had filled from within the adrenal glands or from their hilar regions were assessed

The movements of the contrast medium in veins around the left adrenal gland could be assessed in twenty four instances, the flow was in the central direction in twenty three and towards the periphery in one (Fig 21) In a further eleven in stances, the conditions could not be assessed, as the contrast medium sometimes thinned out and gave no indication of the direction of flow, or disappeared completely between two films, once no peripheral veins filled despite adequate filling of the central veins

Assessment was possible on the right side in eighteen instances and the contrast medium had flowed centrally in all of them The direction of flow could not be judged in a further three glands, and no veins were filled around four glands although the central veins had filled satisfactorily

## Discussion

*Efferent veins* All adrenal glands were found at the anatomic investigation to have a single draining vein running to the left renal vein or to the vena cava In two instances, a right adrenal vein and a small hepatic vein had a short common stem This finding may be compared with the phlebographic observations in which two adrenal glands on that side out of 36, filled through a stem in common with a small hepatic vein The result differs from the descriptions of other authors

As regards the width of the efferent veins, JOHNSTONE, it is true, gave measure ments but he did not state how his figures were reached nor where the measure ments were taken This information is of importance when the possibilities for catheterizing the vessels are being judged, as the width increases towards the outlet As the circumference of the veins, in anatomic preparations at least is seldom round, not even when they are filled, the width must be calculated by dividing the circumference of the lumen by $\pi$ or by catheterizing with tubes of known diameters As, in the present study, the width was investigated mainly to ascertain the possibility of catheterizing the veins at phlebography the diameter of the tubes was limited to a maximum of 2 42 mm despite the fact that the vessels were in a number of cases wider than the catheter This width corre sponded to the size of the catheter, P E No 240, used at the phlebographic examinations

The largest catheter could in all cases be pushed past the opening of the phrenic vein into the adrenal vein proper on the left side On the right side, it could be inserted in only fourteen out of twenty two adrenal veins while eight

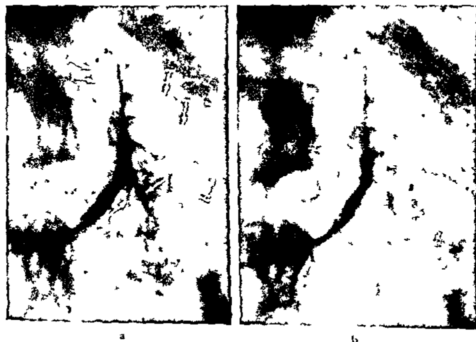



Fig 21 Studies of blood flow in a left adrenal gland a) During injection b) Immediately after termination of the injection The contrast medium flowing back in a central direction in both veins within (→) and outside (↦) the gland The flow in a lateral vein (↦→) could not be assessed

The right adrenal vein sometimes bends sharply just before it enters the vena cava When this occurs, the catheter does not pass in as far as it otherwise reaches at catheterization This is usually of no significance in the angiographic examination but it probably largely explains why blood is often more difficult to obtain from the right side than from the left The opening of the catheter may come too close to the vessel wall with the result that a valvular effect arises In the phlebographic series, 30 ml of blood could be withdrawn from the right adrenal gland for aldosterone determinations at 21 *out of* 36 catheterizations, while the same amount of blood was obtained from the left adrenal gland in *all* the twenty three cases examined by the modified technique which was used in part of the series

*Central veins* The central venous system extends in the alar raphe to the edges of the gland where the 1 to 2 mm thick layers of cortex meet, and consequently the size and shape of the gland may be assessed at phlebography if the venous system has filled completely with contrast *medium* The appearance differs from that usually seen when the vessels fill during arterial angiography It then looks

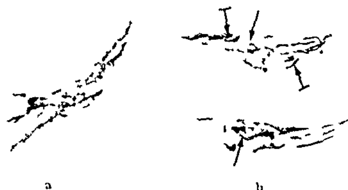



Fig 20 a) Right adrenal gland in the dorsal position from the lateral side Hepatic vein in axial projection b) Section through both adrenal glands with dorsal surface downwards Left gland uppermost Central vein (→) Veins in ventral and dorsal sulci (⊢→) Same case as in figs 18 and 19

veins were too narrow At phlebography 36 catheterizations out of 51 had been successful A statistical analysis using the chi square test revealed no significant differences between the series

It is unlikely that the width of the veins in anatomic preparations differs from the in vivo width Their muscle tissue is largely longitudinal (MARESCH 1921, KUTSCHERA AICHBERGEN 1922, DOBBIE & SYMINGTON 1966, and others), and probably has little effect on the width Appreciable shrinking as a result of formalin fixing can hardly have occurred as the fixation was of a low degree in the central parts of the preparations The tissues in those parts were of normal consistency and colour The probable explanation of the failures at catheterization is that the veins were sometimes too narrow to admit the catheter used at the phlebographic examination The fact that adrenal veins may have a common stem with a liver vein is on the other hand of no particular importance Even in those cases in which this was observed, the vein had its outlet within a small area in the right dorsal quadrant of the vena cava wall, on a level with the twelfth rib In the roentgen studies the liver lobe did not conceal the adrenal gland in question Should this occur, an alteration in the projection should be made Phlebography could perhaps be carried out more often if smaller catheters were also available but in that event the difficulties at catheterization would increase Not only is a finer catheter harder to manoeuver in the vena cava which usually is fairly flat, but it is also more difficult to distinguish on the TV screen If the tip alone were made narrower, there would be a greater risk of small intimal injuries and paravasal leakage of contrast medium A movable inner catheter might give rise to uncontrollable tension irregularities between the two tubes A catheter with an extra long, flexible tip might perhaps be tried however

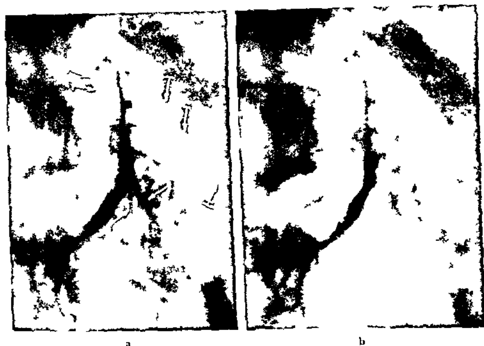



Fig. 21. Studies of blood flow in a left adrenal gland. a) During injection. b) Immediately after termination of the injection. The contrast medium flowing back in a central direction in both veins within (→) and outside (↦) the gland. The flow in a lateral vein (↦→) could not be assessed.

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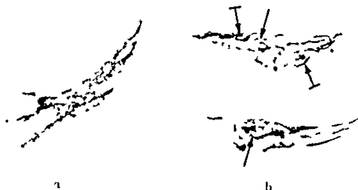



*Fig* 20 a) Right adrenal gland in the dorsal position, from the lateral side Hepatic vein in axial projection b) Section through both adrenal glands, with dorsal surface downwards Left gland uppermost Central vein (→) Veins in ventral and dorsal sulci (↦) Same case as in *figs 18 and 19*

veins were too narrow At phlebography, 36 catheterizations out of 51 had been successful A statistical analysis using the chi-square test revealed no significant differences between the series

It is unlikely that the width of the veins in anatomic preparations differs from the in vivo width Their muscle tissue is largely longitudinal (MARESCH 1921, KUTSCHERA-AICHBERGEN 1922, DOBBIE & SYMINGTON 1966, and others), and probably has little effect on the width Appreciable shrinking as a result of formalin fixing can hardly have occurred, as the fixation was of a low degree in the central parts of the preparations The tissues in those parts were of normal consistency and colour The probable explanation of the failures at catheterization is that the veins were sometimes too narrow to admit the catheter used at the phlebographic examination The fact that adrenal veins may have a common stem with a liver vein is on the other hand of no particular importance Even in those cases in which this was observed, the vein had its outlet within a small area in the right dorsal quadrant of the vena cava wall, on a level with the twelfth rib In the roentgen studies the liver lobe did not conceal the adrenal gland in question. Should this occur, an alteration in the projection should be made Phlebography could perhaps be carried out more often if smaller catheters were also available but in that event the difficulties at catheterization would increase Not only is a finer catheter harder to manoeuver in the vena cava, which usually is fairly flat, but it is also more difficult to distinguish on the TV screen If the tip alone were made narrower, there would be a greater risk of small intimal injuries and paravasal leakage of contrast medium A movable inner catheter might give rise to uncontrollable tension irregularities between the two tubes A catheter with an extra long, flexible tip might perhaps be tried however




Fig. [illegible] Studies of blood flow in a left adrenal gland. a) During injection. b) Immediately after termination of the injection. The contrast medium flowing back in a central direction in both veins within (→) and outside (↦) the gland. The flow in a lateral vein (↦) could not be assessed.

The right adrenal vein sometimes bends sharply just before it enters the vena cava. When this occurs the catheter does not pass in as far as it otherwise reaches

from the right side than from the left. The opening of the catheter may come too close to the vessel wall, with the result that a valvular effect arises. In the phlebographic series 30 ml of blood could be withdrawn from the right adrenal gland for aldosterone determinations at 21 out of 36 catheterizations, while the same amount of blood was obtained from the left adrenal gland in all the twenty three cases examined by the modified technique which was used in part of the series.

*Central veins.* The central venous system extends in the alar raphe to the edges of the gland where the 1 to 2 mm thick layers of cortex meet, and consequently the size and shape of the gland may be assessed at phlebography if the venous system has filled completely with contrast medium. The appearance differs from that usually seen when the vessels fill during arterial angiography. It then looks

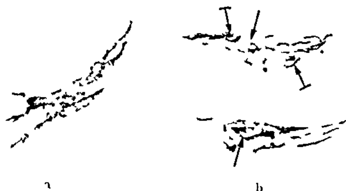



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buffer against the movements of the diaphragm, might have some functional connection with the adrenal glands, whether for instance it serves as a raw material depot for hormone production If this were so, transportation would then take place through the extraglandular veins This would presuppose some form of portal circulation A similar intraglandular arrangement of portal type between the reticulate zone and the cortical cuffs which enclose many veins in the medulla (Fig 4) has been described by VELICAN (1947)

## Conclusions

1 Infusion of diluted Mixobar in the vena cava produced intense contrast filling of its tributaries down to a diameter of 0 03 mm

2 Among 22 adrenal glands on the right side and the same number on the left, drainage occurred through a single vein in every instance In two cases the right adrenal vein had a terminal stem in common with a small hepatic vein, in the others the vein ran the usual course to the vena cava or left renal vein

3 The right adrenal vein was in 14 instances catheterized with a catheter of 2 42 mm diameter This size was too large for the other eight glands The right adrenal vein could be catheterized in approximately the same number of cases at epinephro-phlebography A probable cause of unsuccessful catheterizations was that the adrenal vein was too narrow to admit this catheter

4 The fact that an adrenal vein has a short stem in common with a small hepatic vein is of no particular importance It filled through the common stem, which opened in the usual way into the right posterior quadrant of the vena cava, at the level of the twelfth rib

5 The venous system of the adrenal glands had the same appearance in anatomic specimens as at epinephro-phlebography The contrast filled veins permitted detailed assessment of the size and shape of the glands

## SUMMARY

The adrenal venous system was studied in twenty two post mortem cases A single draining vein was found to run from the right gland to the vena cava and from the left gland to the left renal vein Eight veins were however too narrow for catheters of the size used in a previous epinephro-phlebographic series in which the catheterizations failed to the same extent The right adrenal vein and a hepatic vein had sometimes a terminal stem in common but this did not prevent phlebography The intraglandular veins appeared similar in both series

## ZUSAMMENFASSUNG

Das Venensystem der Nebennieren wurde in 22 post mortem Fallen untersucht Es wurde gefunden dass eine einzelne ableitende Vene von der rechten Nebenniere zur Vena cava und von der linken Nebenniere zur linken Nierenvene führt Acht Venen waren jedoch zu eng fur die Katheter derselben Grosse wie sie bei einer vorhergehenden Nebennieren

more like an arrowhead, with the contrast medium visible mainly at the edges on the cranial aspect, notwithstanding that the margins are thinnest at that site Contrast filling thus takes place most easily in those parts of the gland that consist solely of cortex. The information provided by arterial angiography may be increased if the examination is performed under increased pulmonary pressure and after injection of adrenalin, as the adrenal arteries are relatively insensitive to this hormone which contracts other vessels (RIGLER & ROTHBERGER 1927, KAHN 1967, LINDVALL & SLEZAK 1969) However, the true configuration of the adrenal glands may be assessed with certainty only during a distinct venous phase, and such a phase is best obtained by phlebography

*Peripheral veins* The venous system outside the adrenal glands consists partly of vessels in direct contact with the central veins They may be demonstrated at phlebography and as a rule can be distinguished from the central vessels This applies also to the vessels in sulci, especially if different projections are used The flow of the contrast medium could be assessed in 42 out of 61 glands in the phlebographic material, it flowed centrally in 41 instances and towards the periphery in only one case These observations applied to patients with essential or renal hypertension examined in the supine position

In the anatomic studies, many veins were seen running for long distances over the surface of the adrenal glands between the capsule and cortex This was true both for the veins in sulci, some of which opened into the central veins, and for the other veins that ran past the adrenal glands in different directions and could not be demonstrated at phlebography Like most of the concomitant veins, they were located on the other side of the cortical capillary network

The arrangement is difficult to explain In few other parts of the body have veins been encountered that run for a similar distance through parenchymatous organs or that have had this type of contact with their surface without branches to the glands possible to detect macroscopically Another feature should also be mentioned, namely the thick layer of fat that surrounds the kidneys and especially the adrenal glands A fatty capsule of this nature does not envelop other organs of the body, nor is it found around other hormone-producing, lipid-bearing glands Because of the crest, the dorsal, fat-facing surface of the adrenal glands is large, and the fat is thickest on the dorsal aspect When during adolescence the adrenal glands develop and the venous musculature becomes stronger (HEINIVAARA 1953/54), this fat increases in thickness (VELICAN & VELICAN 1949)

As both the adrenal glands lie well-protected against trauma behind ribs, transverse processes of the vertebrae, and thick layers of muscle, the fat would seem to be unnecessary as a mechanical protection It is perhaps not unreasonable to wonder whether the periglandular fat, in addition to its probable function as a

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Phlebographie Serie verwendet wurden und bei der die Katheterisierung im gleichen Aus mass missgluckte Die rechte Nebennierenvene und eine Lebervene hatten in einigen Fal len einen gemeinsammen terminalen Stamm, was aber d e Phlebographie nicht unmoglich machte Die intraglandularen Venen traten in beiden Serien in ahnlicher Weise hervor

## RÉSUMÉ

L auteur a etudie sur vingt deux sujets d autopsie le systeme veineux surrenalien Il a trouve une veine de drainage unique allant de la surrenale droite a la veine cave et de la surrenale gauche a la veine renale gauche Cependant huit veines etaient de calib e trop petit pour les catheters utilises dans une serie precedente de phlebographies des surrenales serie dans laquelle le catheterisme avait echoue dans la meme proportion de cas Dans certain cas la veine surrenale droite et une veine hepatique avaient un tronc terminal com mun mais ceci n empeche pas la phlebographie Les veines intra glandulaires avaient le meme aspect dans ces deux series

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## Case reports

*Case 1* Woman, aged 44, who since the age of 13 had been on insulin for diabetes mellitus. Long history of left otitis media, occasionally acute. She suddenly developed pain in the neck and left ear, with raised temperature. ESR 136 mm/h, normal cerebrospinal fluid. *Roentgen examination revealed a diffuse retropharyngeal* soft tissue swelling but normal osseous structures (Fig 1a). A week later, a peritonsillar abscess was incised. Cultures were negative and the symptoms gradually receded.

Severe cervical symptoms re-appeared about 7 weeks later. The cervical spine was rigidly fixed but no abnormal neurologic signs were apparent. ESR was 133 mm/h, the *anti staphylolysin titre was markedly* elevated (26 IU). Subsequent roentgen examination disclosed destruction of the base of the odontoid process and a larger retropharyngeal soft tissue swelling (Fig 1b). Biopsy of the retropharyngeal region indicated chronic unspecific inflammation. A Glisson sling relieved the pain.

Tonsillectomy was performed about 4 weeks later. During the following months the symptoms *remained* unchanged and all movements of the cervical spine were resented. ESR was between 40 and 60 mm/h. Roentgen examination about 6 weeks after tonsillectomy revealed complete destruction of the odontoid process and erosion of the anterior arch of the atlas.

About 2 months later, the pain in the neck increased and the ESR rose. Further biopsy of the epipharynx showed inflammation of an unspecific nature. There was no evidence of tuberculosis.

The patient was re-admitted to hospital 3 months later, complaining of pain and stiffness *of the neck, loss of taste perception and difficulty in pronouncing complicated words.* Movement of the cervical spine was markedly decreased, with paralysis of the glossopharyngeal and hypoglossal nerves, but no abnormalities of the extremities were present. ESR was between 50 and 70 mm/h, white blood cell count 8 000. Cerebrospinal fluid count 1 000 white blood cells (916 polynucleated and 84 mononucleated), Pandy ++, Nonne +. *Cultures were negative.*

Roentgen examination revealed complete absence of the odontoid process, destruction of the right atlanto-axial joint and right sided subluxation of the atlas on the axis. Sclerosis of the clivus and thickening of the floor of the sphenoidal sinus were present. The retropharyngeal soft tissues, which at the first examination were diffusely thickened, had become narrower distally *and formed a localized expansion in front of the atlas and axis (Fig 1* c and d). The patient was fitted with a collar and received large doses of streptomycin and penicillin for two to three months. She was discharged after four weeks in hospital. She gradually improved and eventually returned to work.

The patient was seen at control examination seven years after recovery. There was some residual cervical stiffness and limitation of movements. The *anti staphylolysin titre* was normal (0.5 IU). Roentgen examination disclosed bony ankylosis between the atlas and the axis (Fig 1 e and f).

*Case 2* Man, aged 43, with history of peritonsillar abscesses, suddenly developed pain and stiffness in the neck; he consulted a private practitioner. The symptoms became worse but roentgen *examination a few weeks later disclosed no noteworthy* changes in the cervical spine (Fig 2a).

The patient was admitted to hospital 6 weeks later. The cervical spine was fixed in slight flexion and right rotation. The mucous membranes of the pharynx were red. The submandibular lymph nodes were enlarged and lymph nodes could also be palpated distal

FROM THE ROENTGEN (DIRECTOR B BRODEN) AND ORTHOPAEDIC (DIRECTOR MAC FELLANDER) DEPARTEMENTS, ST GORANS SJUKHUS, STOCKHOLM, SWEDEN

# DESTRUCTION OF THE ODONTOID PROCESS DUE TO ATLANTO-AXIAL PYOGENIC SPONDYLITIS

by

S AHLBACK and S COLLERT

Absence of the odontoid process is rare Most of the cases published have been considered to be congenital malformations KARLEN (1962) found 26 such cases in the literature and added one case of his own, GWINN & SMITH (1962) reported 22 cases from the literature, and four cases of their own A few cases in which the odontoid process disappeared between two roentgen examinations have recently been reported The absorption of the odontoid process was interpreted as a tuberculous manifestation in a case described by GWINN & SMITH, and as a *post traumatic phenomenon in the cases of FREIBERGER et coll* (1965) and FIELDING (1965)

Pyogenic atlanto-axial osteomyelitis has been described in the literature ODELBERG-JOHNSON (1931) reported a case of unilateral arthritis, FRANK (1944) one with a pathologic fracture of the odontoid process, and LEACH et coll (1967) a case with small erosions in the odontoid process and the anterior arch of the atlas The following two cases of pyogenic atlanto-axial osteomyelitis with complete disappearance of the odontoid process appear to be the first ones to have been reported

Submitted for publication 26 September 1969

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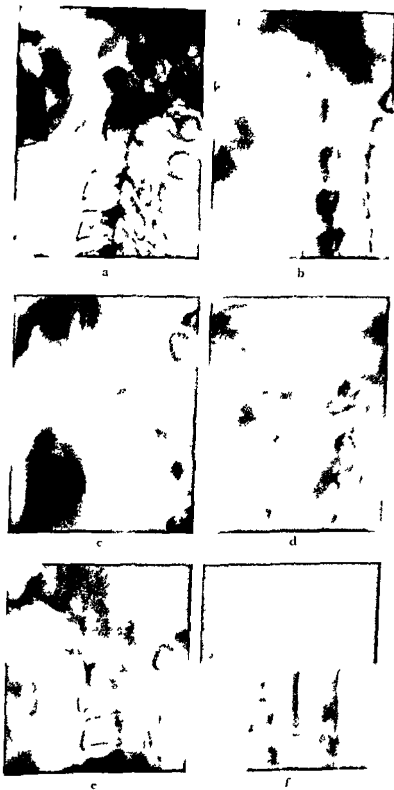
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Roentgen examination revealed complete absence of the odontoid process, destruction of the right atlanto-axial joint and right sided subluxation of the atlas on the axis Sclerosis of the clivus and thickening of the floor of the sphenoidal sinus were present The retropharyngeal soft tissues which at the first examination were diffusely thickened, had become narrower distally and formed a localized expansion in front of the atlas and axis (Fig 1, c and d) The patient was fitted with a collar and received large doses of streptomycin and penicillin for two to *three months She was discharged after four weeks in hospital* She gradually improved and eventually returned to work

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F g 1 (for legend see opposite page)

to the left mastoid process ESR was raised, from 7 mm/h on admission to 110 mm/h one week later The white blood cell count was 7 900, the differential count showed no note worthy change Electrophoresis showed some increase of alfa 1 and alfa 2 globulin The anti streptolysin titre (200 IU) and the anti staphylolysin titre (1 0 IU) were normal The tuberculin test was negative

Roentgen examination including tomography revealed complete destruction of the odontoid process left atlanto-axial arthritis and diffuse swelling of the retropharyngeal soft tissues above the larynx The atlas was subluxated to the right as well as anteriorly and caudally on the axis (Fig 2b) Roentgen examinations of the skull, chest, thoracic and lumbar spine pelvis and the hip joints were negative Cytologic examination of biopsy material from a lymph node showed unspecific inflammation The retropharyngeal space and the left atlanto axial joints were punctured under fluoroscopy but no material could be withdrawn with a fine gauge needle

The patient was treated with cloxacillin per os and Crutchfield traction and finally the atlas and the axis were joined posteriorly with wire and autologous bone grafts The patient improved rapidly and was discharged from hospital

Roentgen examination at control 5 weeks later demonstrated that the retropharyngeal soft tissues were less prominent (Fig 2c) He returned to work 2 months later and 2 months after this was free of symptoms except for some limitation of cervical movements Roentgen examination demonstrated almost complete absence of the odontoid process and bony ankylosis of the left atlanto-axial joint (Fig 2, d and e)

## Discussion

The history and the course of the disease in these two cases were similar The odontoid process gradually disappeared and unilateral atlanto-axial and subluxation could be demonstrated Both patients had retropharyngeal soft tissue swellings, and the ESR was markedly elevated Both patients recovered with only some limitation of movement of the cervical spine The odontoid process remained absent at control examinations, in Case 1 no less than 7 years

Absence of the odontoid process has usually been considered to be congenital Trauma has been advanced by FREIBERGER et coll (1965) and by FIELDING (1965) as the cause for disappearance of the process. FREIBERGER et coll described a girl aged 2 1/2 years who had a large retro[illegible] al soft tissue [illegible] light trauma [illegible] After about

Fig 1 (see on [illegible] iffuse widening of retro- [illegible] 2 1/2 months after onset [illegible] visible c) and d) Frontal [illegible] he odontoid process with [illegible] vards and to the right on [illegible] zed expansion of the upper retropharyngeal space sclerosis of clivus, and thickened floor of spheno d sinus e) and f) Frontal and lateral tomograms 7 years after recovery Bony bridge between the anterior arch of atlas and body of the axis bony ankylosis of both intervertebral joints regression of the retropharyngeal soft tissue swelling and of the sclerosis of the clivus

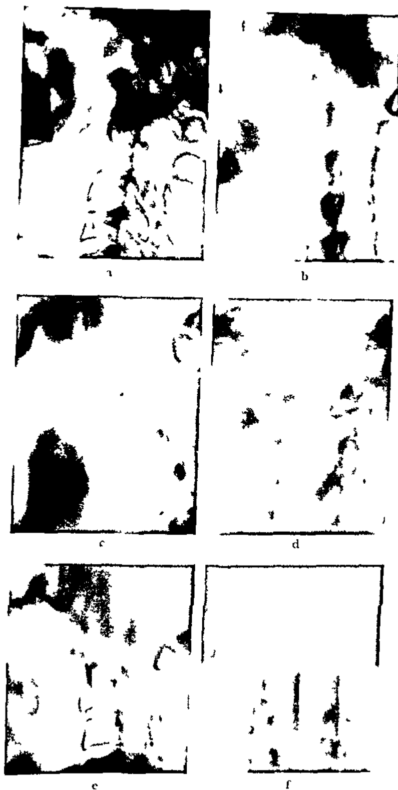


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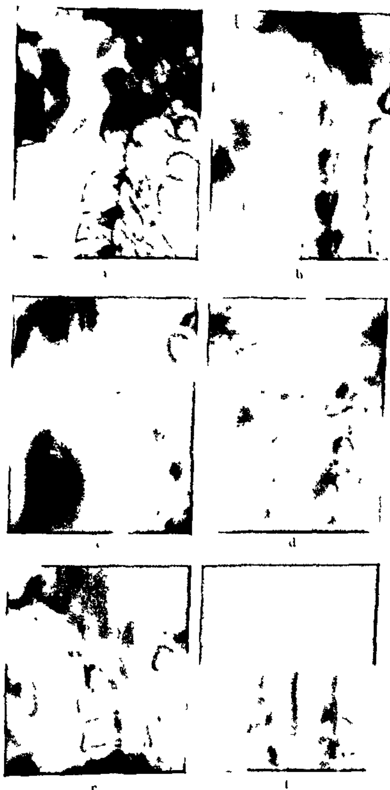


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The patient was treated with cloxacillin per os and Crutchfield traction and finally the atlas and the axis were joined posteriorly with wire and autologous bone grafts. The patient improved rapidly and was discharged from hospital

Roentgen examination at control 5 weeks later demonstrated that the retropharyngeal soft tissues were less prominent (Fig 2c) He returned to work 2 months later and 2 months after this was free of symptoms except for some limitation of cervical movements Roentgen examination demonstrated almost complete absence of the odontoid process and bony ankylosis of the left atlanto-axial joint (Fig 2, d and e)

## Discussion

The history and the course of the disease in these two cases were similar The odontoid process gradually disappeared and unilateral atlanto-axial and subluxation could be demonstrated Both patients had retropharyngeal soft tissue swellings, and the ESR was markedly elevated Both patients recovered with only some limitation of movement of the cervical spine The odontoid process remained absent at control examinations, in Case 1 no less than 7 years

Absence of the odontoid process has usually been considered to be congenital Trauma has been advanced by FREIBERGER et coll (1965) and by FIELDING (1965) as the cause for disappearance of the process FREIBERGER et coll described a girl aged 2 1/2 years who had a large retropharyngeal soft tissue ... [illegible] ...mparatively slight trauma ... disappeared After about

... widening of retro- ... months after onset ... c) and d) Frontal ... tomograms 9 months after onset Complete absence of the odontoid process with bone defects at the right atlanto-axial joint the atlas is displaced forwards and to the right on the axis Localized expansion of the upper retropharyngeal space sclerosis of clivus, and thickened floor of sphenoid sinus e) and f) Frontal and lateral tomograms 7 years after recovery Bony bridge between the anterior arch of atlas and body of the axis bony ankylosis of both intervertebral joints regression of the retropharyngeal soft tissue swelling and of the sclerosis of the clivus



a



b



c



d



e



f

Fig. 1 (for legend see opposite page)

to have been inflammatory rather than traumatic in nature There was no history of trauma in our cases

Rheumatoid arthritis may give rise to erosions of bone and to a pathologic fracture of the odontoid process (MARTIN & BOLE 1968) The process is usually affected only in advanced cases in which there are other manifestations of the disease There is no report of complete destruction of the odontoid process in such cases GWINN & SMITH (1962) stated that their case was the first one described of the disappearance of the odontoid process The patient was a girl, aged 4 1/2 years, with areas of rarefaction in the odontoid process, seven years later the process had completely disappeared The authors considered that tuberculosis was the probable cause of the destruction *This diagnosis was considered in our* Case 1 but rejected In our Case 2 the tuberculin test was negative

Most cases of pyogenic spondylitis are characterized by an acute onset with localized pain and a high ESR (usually over 100 mm/h) and frequently increased anti staphylolysin titre Most cases have a tendency towards rapid recovery and there is a low incidence of relapse (AHLBACK et coll 1969) The two cases now published follow this pattern

Bony changes can often be demonstrated only after 3 to 6 weeks The microorganism responsible for the disease could not be demonstrated in either case However, the markedly increased anti staphylolysin titre, which later became *normal, strongly suggests a staphylococcus infection in our Case* 1

The atlanto-axial region is difficult to examine Frontal and sagittal tomography was necessary in both our cases to demonstrate the extension of the destructive changes in the odontoid process as well as in the intervertebral joints Pyogenic spondylitis in other parts of the spine is almost always localized within or close to the intervertebral disk Relatively large intervertebral joints take the place of disks between the atlas and the axis The arthritis in these joints probably *occurs before the destruction of the odontoid process* This was evident in Case 1, in which the base of the process was seen to be destroyed before the whole process disappeared

## SUMMARY

Two cases of pyogenic atlanto axial spondylitis with complete disappearance of the odontoid process are reported The differential *diagnosis* in these rare cases is discussed

## ZUSAMMENFASSUNG

Es wird uber zwei *Fallen von pyogener* Osteomyelitis des Atlas und Epistropheus be richtet, in denen der Zahnfortsatz des Epistropheus vollstandig zerstort war Die Differen zialdiagnose dieser seltenen Falle wird erortert

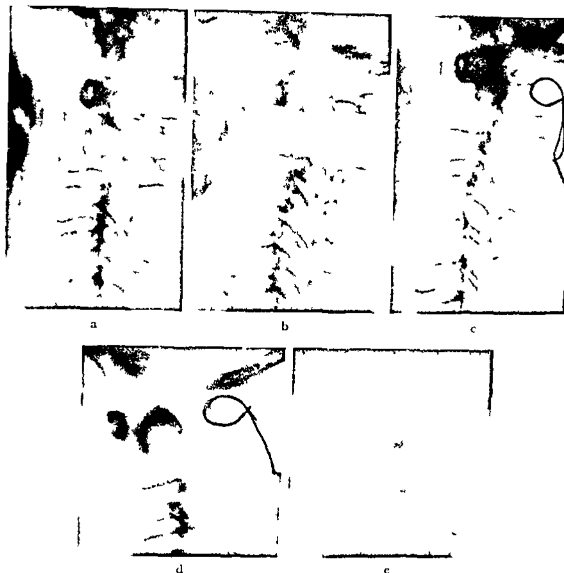



Fig 2 Case 2 a) Two weeks after onset Normal upper cervical region b) Nine weeks after onset The atlas is displaced anteriorly and caudally on the axis diffuse swelling of retropharyngeal soft tissues c) Three and a half months after onset Regression of the soft tissue swelling (fusion performed) d) and e) Eight months after onset All but the base of the odontoid process is absent bony ankylosis of the left atlanto axial joint and persistent atlanto axial misalignment

one and half years the apex of the process could again be demonstrated FIELDING reported a case of a 17-month-old boy, who had marked retropharyngeal soft tissue swelling after trauma but otherwise normal radiographic appearances of the region Seven years later the odontoid process with the exception of the apex was missing These cases bear several similarities to our cases They would appear

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# CORRECTION OF THE PELVIS IN BLADDER EXSTROPHY

## A radiographic analysis

by

PAUL EDHOLM

The theoretical possibility of closing the diastasis of the pubic symphysis in bladder exstrophy by a modified form of osteotomy of the ilium has been investigated. It was believed that this operation might enable a better correction of the pelvis than is possible with the more conventional techniques. Roentgenograms from patients with this anomaly and from a group used as controls, obtained in a radiographic analysis of the orientation of the pelvic bones, were compared. The comparison was based on measurements of the angles between lines joining various skeletal reference points. This method of measurement has the advantage over the measurement of distances in that the determinations are independent of difference in size at different ages as well as in magnification between various radiographic projections.

*Material.* This consisted of 27 cases of exstrophy of the bladder or epispadias, in which urograms, urethrocystograms and ordinary roentgenograms were available. The pelvic structures were clearly discernible in both frontal and lateral projections in sixteen of the cases, in twelve of which bladder exstrophy had been

Submitted for publication 4 November 1969

## RÉSUMÉ

Presentation de deux cas de spondylite a pyogenes atlo axoidienne avec disparition complete de l apophyse odontoide Discussion du diagnostic differentiel dans ces cas peu frequents

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pubis were taken as the centres of gravity and were also approximated The nine lines are referred to in the text by their respective numbers.

The angle that each line formed with the normal to the base plane was measured in the frontal and lateral tracings The direction of the line was marked out, with the aid of an instrument designed for the graphical calculation of angles between skeletal structures (EDHOLM 1966), as a point in a diagram representing the surface of a hypothetical sphere of a radius large in relation to the size of the pelvis and with the femoral head at its centre (Fig 3)

The diagram contained lines representing the meridians and parallels of the sphere, just as on a globe, and oriented so that the north pole represented the direction of the a p projection and the direction of the lateral projection was represented by the left terminal point of the 'equator' in the diagram The diagram thus indicated the hypothetical sphere as viewed from a point located on the normal to the base plane, i e from approximately a cranial direction

As the data in this investigation covered more than one hemisphere it was necessary to use a diagram representing a stereographic projection The surface of the sphere was therefore projected on to a plane by rays coming from the point on the surface that lay farthest from the plane (Fig 4), and with this projection a greater area than one hemisphere can be covered

The directions of the nine lines were represented in the diagram by the points at which the lines produced intersected with the surface of the sphere (Fig 5) All the lines except 5 and 6 were produced in a cranial direction As lines 5 and 6 often coincided with the base plane, their directions could not be determined solely from the angles in the frontal and lateral projections wherefore it was necessary to construct a third projection of the line perpendicular to the base plane, i e the projection whereby the diagram became representative of the sphere (Fig 6) The angle between the line and the direction of the frontal projection was found by computing its tangent as the ratio of the distances on the two films between the points defining the projection of the line on the base plane

Each projection of a line is represented on the sphere by a great circle, two projections thus give two great circles whose points of intersection define the direction of the line With three projections, as used in the case of lines 5 and 6, three great circles are obtained, which form on the sphere a small triangle whose centroid represents the direction of the line

In two diagrams, one for each group, all the lines for each subject were entered as points, the exstrophy series is shown in Fig 5

*Statistics* The various directions of lines for a group of subjects were represented by a group of points in the corresponding diagram, and the dispersion within the group was therefore due to inter subject variations in position during

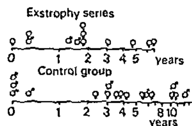



Fig 1 (above) Age and sex of the subjects comprising the bladder exstrophy series and the control group

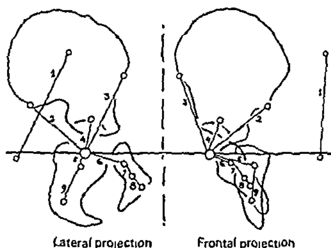



Fig 2 (right) Tracings with the nine reference lines relating to a case of bladder exstrophy The horizontal lines are the base lines

diagnosed, in none of them had osteotomy been carried out They will be referred to below as the exstrophy series

The comparison, or control, group comprised seventeen randomly chosen cases in which urography and urethrocystography had been performed The composition of the two groups with respect to age and sex is presented in Fig 1

Both urography and urethrocystography had usually been carried out in the exstrophy series as well, the urethrocystograms were however generally sufficient for the present purpose since as a rule several frontal and lateral films were available

*Method* The following procedure was uniformly applied Tracings were made of the frontal and lateral projections of the right half of the pelvis on a sheet of transparent paper An approximate reconstruction of the ray path geometry was made from the two roentgenograms A line was drawn on the two tracings to represent a base plane through the two beams passing through the hip-joint in each of the two projections

The following lines were then added to the tracings (Fig 2) between the centres of the first and fifth sacral vertebrae (1), between the centre of the femoral head and the posterior inferior iliac spine (2), the anterior superior iliac spine (3), the centre of the body of the ilium (4), the centre of the body of the ischium (5), the centre of the body of the pubis (6), between the centre of the body of the pubis towards the lateral margin of its superior ramus (7), a tangent to the medial part of the axis of the superior ramus of the pubis (8), from the centre of the body of the ischium to the first part of the ramus (9)

The centre of the femoral head and the long axis of the ischiatic and pubic rami were approximated The centres of the bodies of the ilium, ischium and

pubis were taken as the centres of gravity and were also approximated The nine lines are referred to in the text by their respective numbers.

The angle that each line formed with the normal to the base plane was measured in the frontal and lateral tracings The direction of the line was marked out, with the aid of an instrument designed for the graphical calculation of angles between skeletal structures (EDHOLM 1966), as a point in a diagram representing the surface of a hypothetical sphere of a radius large in relation to the size of the pelvis and with the femoral head at its centre (Fig 3)

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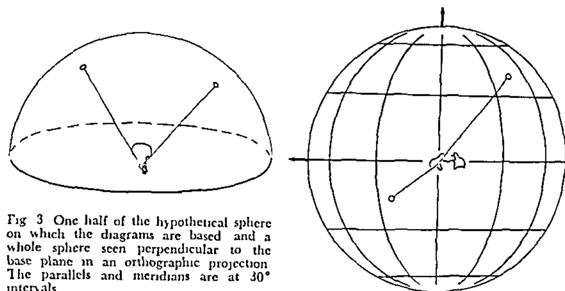


Fig 3 One half of the hypothetical sphere on which the diagrams are based and a whole sphere seen perpendicular to the base plane in an orthographic projection The parallels and meridians are at 30° intervals

the radiographic examinations and to biologic factors The error of method should also be considered but this has been shown to be negligible compared to other sources of error (EDHOLM 1966)

Each of the nine lines had two distributions, one for the exstrophy series and the other for the controls The mean direction of each distribution was calculated, as was the accuracy of this determination

The geometric basis for a distribution of directions is the surface of a sphere The range of the distribution usually occupies such a small part of the sphere that it can be approximated to a plane, and then the Gaussian distribution, which is based on a plane of infinite extent, can be used In this study however the range of distribution was too great for this to be possible and therefore a theory developed by FISCHER, which is appropriate for measurements on a sphere, was applied

Each member of distribution was regarded as a vector A diagram was constructed on a transparent sheet so that, combined with the original diagram, it enabled the direction cosines in relation to the three axes of projection to be read off for each member The resultant (R) of all the vectors in the distribution was then calculated Its direction was the mean direction, and the accuracy of the determination was represented by a circle of confidence about this direction If the probability that the true mean direction lies outside the circle of confidence is denoted by ($P$) and the cosine of the angle between the calculated mean direction and lines to the circle is ($C$) we have, according to FISCHER,

$$1-C=\frac{N-R}{R}\left[\left(\frac{1}{P}\right)^{1/(N-1)}-1\right]$$

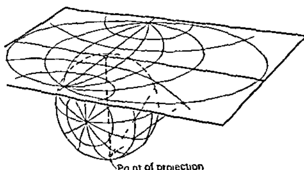



Fig 4 Stereographic projection of the surface of a sphere onto the base plane, the point of projection being indicated by an arrow

where ($N$) denotes the number of members composing the group The true mean direction is the mean direction for the population the examination of which is limited to a sample The circles of confidence at the 5 % level were calculated for all the directions in the two groups of subjects. The mean directions and circles of confidence were then entered in a new diagram (Fig 7) The two groups were examined and compared by means of the instrument

## Results

The differences between the exstrophy series and the control group were considered to be due largely to differences in rotation of the individual lines and of the three pelvic bones An attempt was also made to represent the differences between the two groups as a single rotation of one half of the pelvis as a unit

*Ilium* A comparison between the two groups was made as regards the mean directions of the three lines 4, 2 and 3, i e the lines from the femoral head to the body and the two spines of the ilium The differences were ascribable to a rotation about an axis through the sacro-iliac articulation In the exstrophy series the ilium was rotated outwards and upwards, with the result that the symphysis was widened The axis of rotation lay in a ventrocraniolateral direction, as determined graphically with the instrument

There was no appreciable difference in the shape of the ilium The angle between lines 2 and 3 was 92° in the exstrophy series and 88° in the controls, a difference that is not significant

*Acetabulum* The mean directions of the three lines 4, 5 and 6, from the femoral head to the centres of the ilium, ischium and pubis, respectively, formed

Fig 5 Stereographic projection of the directions of the nine lines for measurement in cases of exstrophy of the bladder The parallels and meridians are at 30° intervals

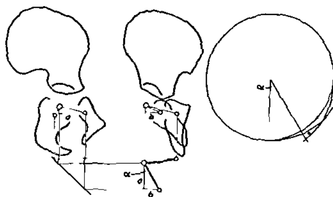



Fig 6 Method of calculating the directions of lines 5 and 6, using lateral (*left*) and frontal (*middle*) projections and constructing a stereographic diagram (*right*) The projection of the lines on the base plane is constructed below the frontal projection The angle between the
al projection is obtained from tan $\alpha = b/a$
*the sphere by three great circles, the parts*
, the centroid of which denotes the direc
tion of the line (small circle)

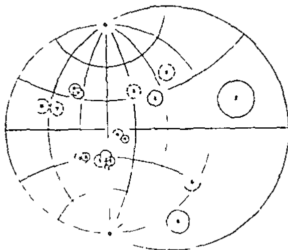


*Fig 7* Circles of confidence at the 5 % level for the nine lines. The exstrophy series is represented by the full-drawn circles and the control group by the dashed circles

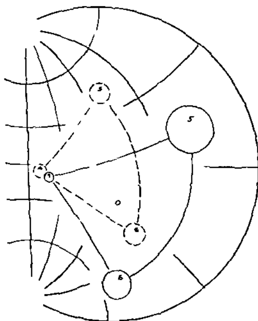


*Fig 8* The orientation of the acetabulum in the exstrophy series (triangle formed by the broken lines) The small circles indicate the positions of the centroids.

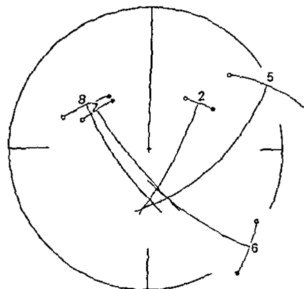



Fig 9 Construction of a common axis of correction for line 2 and for lines 5, 6, 7 and 8 The filled circles represent the exstrophy series and the open circles the control group the shaded area indicates the probable direction of the axis

a triad that represented the orientation of the fossa in relation to the head (Fig 8) In the diagram the angles between the lines formed a spherical triangle of about the same size in the two groups of subjects The differences were not significant

| Angle between lines | 4 and 5 | 5 and 6 | 4 and 6 |
|---|---|---|---|
| Exstrophy series | 84 | 67 | 76 |
| Control group | 73 | 76 | 75 |

The triangle was oriented differently in the two series and this was ascribable to a rotation about an axis having a cranioventral direction The rotation was 15° for line 6, 42° for line 7, and 25° for line 8, values that were on an average greater than those recorded for the ilium The rotation of the centroid of the triangle was 31° The acetabulum faced in the caudolaterodorsal direction in the exstrophy series and caudolaterally in the controls The larger value for the acetabulum triad may be accounted for by assuming that it first described a rotation identical with that of the ilium and then a further rotation about an axis through the femoral head

*Ischium and pubis* The difference between the two groups in respect of the direction of lines 9 and 7, i e from the centres of the bodies of the ischium and pubis towards their resepective rami, could be ascribed to a rotation about an axis with a cranioventral direction and of the same magnitude as the rotation of the ilium A notable feature, however, was the additional rotation that the

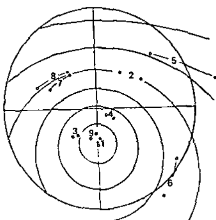



Fig 10

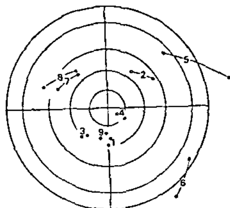



Fig 11

Fig 10 Tentative diagram with a correction axis (+) forming a ventral angle of 37 5° with the normal to the base The parallel circles are centred on the axis intervals of 20° The filled circles represent the exstrophy series

Fig 11 Same construction as in fig 10 but with the parallel circles centred on the normal to the plane

centres of these bones described about an axis through the femoral head, this, however, was unaccompanied by any changes in the direction of the long axes No obvious difference in the shape of the ischium was observed between the two groups, which was however the case with respect to the pubic bone In the control group the superior ramus was well developed and curved medially, with a mean angle of 13° between lines 7 and 8, and formed a sharp junction at the symphysis with the inferior ramus All these characteristics were less prominent in the exstrophy series The superior ramus was less well developed and the mean angle between lines 7 and 8 was only 4°, the difference of 9° between the two groups is not significant (10 30° at the 5 % level) The superior ramus continued in a shallow arc over into the inferior ramus

*The hemi pelvis* Because of the possibility of correction through osteotomy it was considered convenient to regard the difference between the two groups as being due to a single rotation of each half of the pelvis in the exstrophy series In order to find the axis for this rotation the following construction was performed with the instrument for each line (Fig 9)

The two mean directions for the two groups were joined by an arc of a great circle, through the midpoint of which, and perpendicular to it, another arc of a great circle was drawn A rotation that makes one mean direction coincide with

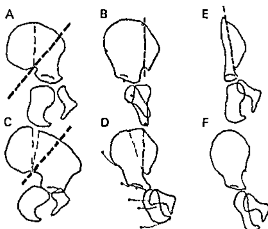



Fig 12 Lateral and frontal projections (A B) in a patient with bladder exstrophy aged 17 months Rotation about a cranioventral correction axis is constructed graphically in (C) and (D) Rotation about a craniolateral axis is presented in (E) *The frontal projection of* the pelvis of a control subject aged 10 months is seen in (F)

the other has its centre on this new arc Such arcs were drawn for all the lines except 1, 3, 4 and 9, the directions of which deviated only slightly from that of the correction axis The arcs for the other lines intersected within a small region which indicated an axis having a cranioventral direction and making an angle of 30 to 45° with the normal to the base A diagram containing all the mean *directions was produced with a series of circles drawn about an axis at a ventral* angle of 37 5° with the normal to the base (Fig 10), these circles denoted the direction of movement in a rotation about this axis The difference between the two groups was found to be ascribable to a single rotation of the hemi pelvis By rotating the pelvis of the exstrophy patient back about this axis, an acceptable *correction of all the lines should be obtainable The differences between the* groups in respect of lines 1, 3, 4 and 9 were so small that the circles of confidence intersected (Fig 7), and the direction of the correction was therefore not well defined, this would account for the deviations from the rest of the pattern displayed by lines 1 and 3

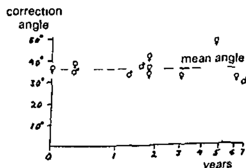



Fig 13 Correction angles for the subjects composing the exstrophy series sex and age being indicated

## Discussion

In iliaca-osteotomy by the methods in current use an attempt is made to correct the malposition by bilateral division of the ilium just lateral to the sacroiliac articulation and then by compression of the pelvis on each side of the osteotomy make the parts meet in the midline (SCHWARTZMANN & SCHULZ, O PHELAN 1963) The osteotomy gap, which mostly forms a small lateral angle to the long axis of the body, is the axis for the corrective rotation

A diagram of the case series, with circles about an axis coincident with the normal to the base plane, is presented in Fig 11, this axis can be seen to be roughly parallel to the long axis of the body The circles denote the paths of rotation about the axis and it will be noted that they do not entirely correspond with the changes in direction required to bring the exstrophy series into agreement with the control group

A graphically constructed a p projection of a pelvis after osteotomy, in which *the axis of correction has been given a small lateral angle, is shown in Fig 12 E,* this has been based on the pelvis in Fig 12 A and 12 B The geometric result leaves a good deal to be desired

It is evident from the findings in this study that a cranioventral direction for the correction axis is desirable If the correction were made so that that part of the pelvis which is lateral to the osteotomy could rotate about an axis having this direction and passing through the caudal tip of the osteotomy, the result as far as appearances are concerned would probably be more satisfactory than what could be obtained with a cranially directed axis The validity of this supposition was tested by the following graphic construction. On a.p and lateral films from a case of exstrophy a cranioventral axis was drawn across the caudal tip of a hypothetical osteotomy through the ilium The axis was assumed to be perpendicular to a plane through the caudal tip of the osteotomy and through part of the pubis taken to represent the symphysis after the correction The result of a rotation about this axis was constructed in lateral and frontal projections Fig 12 C and 12 D) After the correction, the pelvis in both projections appeared to be geometrically normal. The rotation will be the minimum achievable with this construction of the correction axis and the acetabulum will have the same orientation as in the control group One disadvantage, however, is that there is no known technical means of effecting the rotation and then immobilizing the structure

A calculation was made for all the twelve cases comprising the exstrophy series to determine the angle of rotation which with this correction would have produced closure of the symphysis. The results are presented in Fig 13 The mean angle of correction was 36° There was no appreciable age variation

## SUMMARY

A radiographic comparison has been made of the orientation of the *pelvic bones in* 12 cases of exstrophy of the bladder and a control group The comparison was based on angles between lines joining various skeletal reference points, the calculations being performed graphically with a special instrument Corrective rotation of the pelvic halves about a cranio ventral axis in osteotomy for this deformity of the pelvis would apparently provide an accept able geometric result

## ZUSAMMENFASSUNG

Ein radiographischer Vergleich der Orientierung der Beckenknochen bei 12 Fallen mit Exstrophie der Blase gegenuber der einer Kontroll Gruppe wurde vorgenommen Der Ver gleich basiert auf den Winkeln der Linien, die verschiedene Referenzpunkte des Skeletts ver binden, und die Berechnungen wurden graphisch mit einem besonderen Instrument durch gefuhrt Eine korrigierende Rotation der Beckenhalften um eine cranio ventrale Achse bei einer Osteotomie wegen dieser Deformation des Beckens wurde wahrscheinlich zu einem annehmbaren geometrischen Resultat fuhren

## RÉSUMÉ

L auteur a fait une comparaison radiographique de l orientation des os dans 12 cas d ex strophie vesicale et dans un groupe de sujets temoins La comparaison a ete basee sur les angles formes par des lignes joignant differents points osseux de reference les calculs ont ete faits graphiquement au moyen d un instrument special Une rotation corrective des moities du bassin autour d une axe oblique en haut et en avant donnerait apparemment un resultat geometrique acceptable dans l osteotomie pour le traitement de cette malformation du bassin

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# SEMI-AUTOMATIC CONSTRUCTION AND COMPUTER ANALYSIS OF VOLUME CURVES AND PRESSURE-VOLUME CURVES IN LEFT VENTRICULAR CINEANGIOGRAPHY

by

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*Different methods* have been described for calculating the volumes of the cardiac chambers, especially the left ventricle, with the aid of angiocardiography The construction of volume curves from the left ventricle by full size angiocardiography with an exposure frequency of 6 per second has also been attempted by using data from several cardiac cycles (DODGE et coll 1956, 1966 and ARVIDSSON 1958, 1961, inter alios) Cineangiocardiography with exposure frequencies of 100 per second or more are however more suitable for building such curves (RUSHMER & THAL 1951, CHAPMAN et coll 1958, 1966 GRIBBE et coll 1959 BRUN et coll 1966, inter alios)

The routine use of left ventricular volume curves produced with the aid of angiocardiography and pressure volume curves, and their further analysis, should mean considerable diagnostic and probably also prognostic gains in the assessment of patients with cardiac disease (DODGE et coll, BRUN et coll inter alios) Increased information on the state of the myocardium, better

Submitted for publication 5 September 1969

evaluation of the relative importance of so-called valvular and myocardial factors, and a more reliable assessment of the effect of surgical and other therapeutic measures should thus be obtained

In spite of these possibilities, however, such curves and their further analysis have as yet been put to no practical use in cardiology The reason for this is the large amount of information that needs to be analysed to produce results. The task of manually constructing and analysing the curves is time-consuming The manual construction of a volume curve for the left ventricle during one cardiac cycle (40 exposures/second) appears to require a working time of about 8 hours Methods for automatic or semi-automatic construction of pressure-volume curves are desirable and the need of computer aid for their analysis is clear

The technique for semi automatic construction of pressure curves, pressure-volume curves and the computerized subsequent analysis of these curves will be described

*Material and Methods* The material consisted of the cineangiocardiograms obtained from the left ventricle by catheterization and angiocardiography, and simultaneous pressure recordings from the left ventricle, aorta, and sometimes one other heart chamber The pressure recordings were made either via teflon catheters introduced transseptally into the left atrium or left ventricle, or via grey Ödman catheters passed percutaneously into the left ventricle The pressure in the ascending aorta was recorded as a rule via polythene catheters (PE 160) inserted percutaneously, these were connected to pressure transducers (Elema-Schonander) and the pressures recorded on a Mingograph, type 81 (Elema Schonander) The ECG was recorded by the conventional method simultaneously with the pressure recording The paper speed was 100 mm/second

Contrast medium (usually Isopaque 350) for the angiocardiographies in a dose of about 0 5 ml/kg body weight was injected into *the left atrium via* transseptal catheters or into the left ventricle via catheters inserted in a retrograde direction The injection was given with a Gidlund syringe, with the pressure kept low (3 5 kg/cm²) so as to prevent as far as possible any movement of the catheter and thereby the induction of extra systoles during the injection The roentgen tube was a Siemens rapidly rotating high load tube with a nominal focus dimension of 0 6 mm × 0 6 mm

Cinerecording in one plane was performed by means of a 9″ image intensifier and a 35 mm film camera (Arriflex) at an exposure rate of 40 per second The exposure data were *50 to 70 kV and 325 mA*, *duration* of each cinepulse 0 003 seconds A geometric magnification factor of 1 3 to 1 8 was employed

Gevaert's Scopix G, high definition film was developed for 11 minutes in fine-grain developer A special synchronization arrangement (BJORK 1961), which gives markings both on the cinefilm and via one of the channels on the Mingograph paper, made possible exact synchronization between each frame on the cinefilm and the corresponding segments of the simultaneously recorded pressure curves and ECG

The patient was placed in the supine position for the angiographic examination with the right side rotated upwards towards the image intensifier so that the longitudinal axis and greatest projection of the left ventricle lay as *near as possible on one plane perpendicular* to and in the centre of the beam pathway in the image recording system Before or after the angiocardiography a ruler with millimeter markings was placed in the same position and on the same level as the left ventricle A short cinerecording was made of the ruler, and in this way a reference was obtained on the same film strip as the angiocardiogram for the magnification in the image recording system and in the following projection system

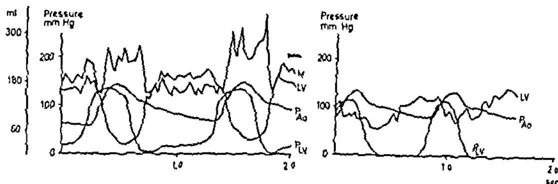
The cinefilms obtained from the left ventricular angiographies were placed in a special plotting projector and projected frame by frame, highly magnified, *on a transparent screen, built into the latter was a recording coordinate system* The contour of the left ventricle was followed manually, and the coordinates required for calculating the volume of the left ventricle were thereby established These coordinates were fed automatically into a writer that punched a tape from which the coordinate values were then supplied to a computer The calibrated pressure curves were obtained from a so called curve reader and the values were fed similarly via punched tape to the computer Recordings from at least two consecutive cardiac cycles with a normal heart rhythm were aimed at, and in most cases obtained

The following mathematical formula was used for the calculation of the left ventricular volume with one cineangiographic projection

$$V=\frac{LD^2}{2}$$

where $D=4A/L$, $V=$ the volume of the left ventricle, $L=$ the longest diameter of the projected area and $A=$ the projected area This formula was studied in autopsy material by DAVILA & SANMARCO (1966) who reported good correlation between the true and the roentgenologically measured volumes of the left ventricle by the method

The muscle mass of the left ventricle was assumed to be equally distributed around the lumen of the ventricle, as depicted in the cineangiocardiograms. The thickness of the muscle wall was measured at the anterolateral wall of the left




Figs 1 and 2 Volume and pressure curves in a patient with moderate aortic insufficiency (left) and in a patient with diffuse myocardial affection (right) M — left ventricular muscular volume, LV — left ventricular volume, $P_{Ao}$ — aortic pressure, $P_{LV}$ — left ventricular pressure

ventricle, where the coordinates for this thickness, at least in diastole, may be determined with considerable reliability For calculation of the volume of the muscle mass of the left ventricle, the left ventricular volume was then subtracted from the volume of a large rotation body comprising both the musculature and lumen of the left ventricle and calculated according to the above formula The muscle volume obtained was then inserted in the same diagram as the volume of the left ventricle

For further analysis, the computer was programmed to calculate the first derivative of the left ventricular pressure curve and the first derivative of the left ventricular volume curves These are presented, like the other data, in the form of automatically drawn diagrams. The pressure-volume curve for the left ventricle was also drawn automatically. This gave the work performed by the left ventricle as well as a graphic presentation of the pressure and volume levels at which this work was achieved The product of the aortic pressure and the first derivative for the volume of the left ventricle was also calculated, this was expressed as a function of time and constitutes a measure of the 'static' work of the heart The pressure difference between the left ventricle and aorta was also calculated The product of this difference and the first derivative of the volume curve was expressed similarly as a function of time and corresponds to the 'dynamic' work of the heart

## Preliminary results

The clinical value of this method cannot be assessed since the technique described above has been used only in about 30 cases The following may be regarded as examples of its possibilities

Curves obtained for a patient with dominating aortic insufficiency of moderate degree are presented in Fig 1 The curves represent, from above

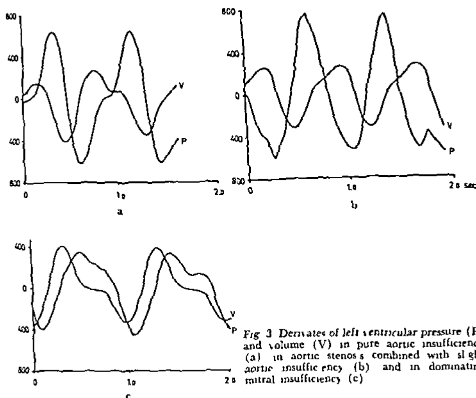



*Fig 3* Derivates of left ventricular pressure (P) and volume (V) in pure aortic insufficiency (a) in aortic stenosis combined with slight aortic insufficiency (b) and in dominating mitral insufficiency (c)

downwards, the left ventricular muscle volume, the left ventricular volume, the aortic pressure and the left ventricular pressure The curve for the muscle volume of the left ventricle varies widely, especially during ventricular systole, while it exhibits a more even and constant course during diastole This probably reflects the fact that it is only in diastole that the technique used for measurement of the left ventricular muscle volume gives a fairly good correlation to the true volume The difficulties in measuring the thickness of the ventricular wall in systole are greater, and the assumptions regarding the distribution of the muscle mass are also probably no longer valid, nor therefore the mathematical formula used The value of the attempts to calculate the muscle volume of the left ventricle is thus uncertain It would be desirable to attempt a correlation between the measured volume and the true volume obtained in an autopsy material It is possible that the muscle volume of the left ventricle in diastole may be fairly well correlated to the true volume, however, and the value obtained in diastole might possibly be usable for further calculations

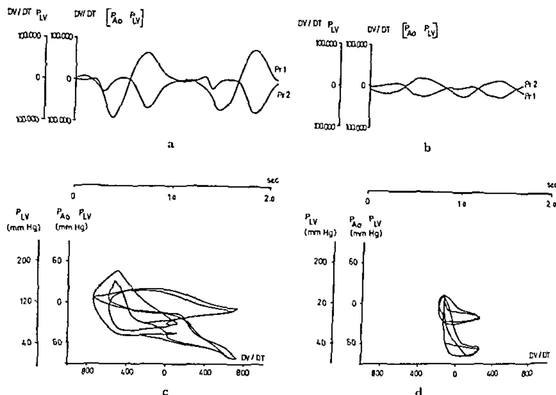



Fig 4 The product of the derivates of left ventricular volume and aortic pressure (Pr 1) and the product of the same derivate and the pressure difference between left ventricle and aorta (Pr 2) a) Moderate aortic insufficiency b) Diffuse myocardial affection c) Integrals of the curves in (a) d) Integrals of the curves in (b)

The volume curve for the left ventricle exhibits a number of variations in diastole Several of these variations are certainly due to artefacts and are subject to interpretation errors, a matter discussed in more detail below The systolic and diastolic volume and the stroke volume for the left ventricle may be obtained directly from the left ventricular curve These values may of course also be recorded directly in numerical form, if desired The stroke volumes could be compared with stroke volume values obtained by the Fick method immediately before the angiocardiographies in five cases with good agreement between the values obtained by the two methods Fig 2 illustrates the left ventricular volume curve and pressure curves for the aorta and left ventricle in a patient with a diffuse myocardial lesion Small and partly irregular volume variations in the left ventricle between systole and diastole are apparent

In Fig 3, examples are presented of the derivatives of pressure and volume in patients with different valvular disorders (P = pressure derivative and V = volume derivative) The pressure and volume derivatives are illustrated for a

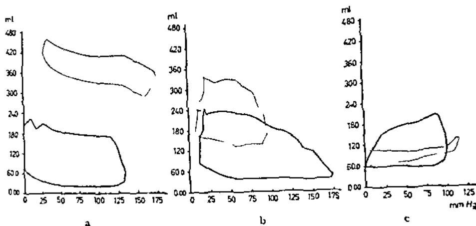



Fig 3 Pressure-volume loops for the left ventricle a) Well compensated aortic insufficiency (solid line) and aortic insufficiency and heart failure (dotted line) b) Moderate aortic insufficiency in two patients c) Dominating mitral insufficiency (solid line) and diffuse myocardial affection (dotted line)

patient with dominating aortic stenosis combined with mild aortic insufficiency in Fig 3a and the derivatives for a patient with dominating mitral insufficiency in Fig 3c The derivatives represent essential differences in the different patients, and it is thus possible that analysis of the derivatives could give detailed and exact information on the contraction pattern of the left ventricle in various cardiac diseases Assessment of the value of these derivatives must be deferred, however, until more experience has been gained and knowledge of their appearances in normally functioning left ventricles obtained

Both the product of the volume derivative and the aortic pressure, as well as the product of the volume derivative and the pressure difference between the left ventricle and aorta, are included in Fig 4 The former product comprises a measure of the 'static' work of the heart, and the latter a measure of its 'dynamic' work The appearances of these curves differ essentially The left ventricle of the patient in Fig 4a may be considered to have a good function, despite the presence of moderate aortic insufficiency, while in the patient in Fig 4b, with the diffuse myocardial lesion, the function of the left ventricle and thereby the work it performs are considerably reduced This is even more clearly evident in Fig 4, c and d, in which the integrals of corresponding curves for the two patients are shown

The pressure-volume curves for the left ventricle express clearly the left ventricular function The area enclosed by the pressure volume curve represents the work of the left ventricle, and from the position of the curve in the diagram

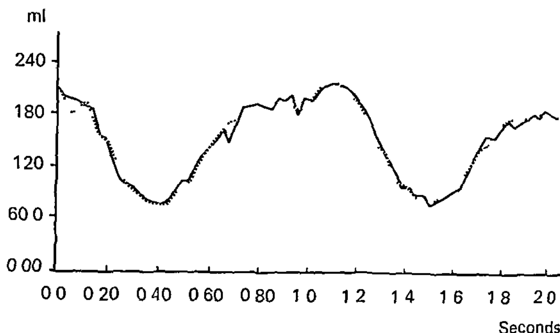



Fig 6 Good agreement between two left ventricular volume curves obtained from double reading of the same cineangiogram with 3 week intervals

the pressure and volume levels at which this work is performed may be observed and determined directly

One of the pressure volume curves in Fig 5a was obtained for a well compensated patient with aortic insufficiency (the same patient as in Fig 1) The left ventricle of this patient had a relatively large work output, at a normal pressure level but a somewhat elevated volume level The other patient (dashed curve) also had aortic insufficiency but was on the verge of cardiac failure, his left ventricle was performing less work and furthermore this lower work output was produced at a very high volume level and at a moderately raised pressure level Similar examples of pressure volume curves in two patients with aortic insufficiency are given in Fig 5b The solid curve indicates moderate aortic insufficiency The left ventricle had a fairly high work output at a somewhat elevated pressure level and at a slightly raised volume level The other patient (dashed curve) also had aortic insufficiency but the left ventricle was performing less work at, especially, a greatly raised volume level The solid curve in Fig 5c represents the left ventricular work in a patient with dominating mitral insufficiency The ventricle probably had a normal work output, achieved at a slightly elevated volume but at a normal pressure level The dashed curve represents the work of the left ventricle in a patient with myocardial insufficiency based on coronary arteriosclerosis The left ventricle was apparently performing

little work at a high systolic volume level but a normal diastolic level and at a normal diastolic pressure

## Discussion

It is important in a study of this kind that the many sources of error that can arise in the collection of primary data and in the subsequent analysis should be considered and eliminated as far as possible Exact pressure recordings are obviously necessary A continuous check as well as careful calibration and supervision of the pressure recording system are therefore essential The paper speed in the Mingograph may possibly vary, investigation into the Mingograph we used disclosed variations not exceeding 1 % With the synchronization system used, which gives markings simultaneously on the Mingograph paper and the cinefilm, minor variations in the paper rate in the Mingograph, and even variations of the exposure frequency in the film camera, are however of little importance in the final evaluation of the data They are of some significance, however, for the appearances of the pressure curves, and to some extent for the visual assessment of the course via the cinefilm

It is also of importance [illegible]
intensifier and film camera, [illegible]
correctly in relation to one ano[illegible]
of the image A simple way of checking that the image recording system is functioning satisfactorily is by recording with this system the image of a fine-mesh square wire network Variations in the ideal recording conditions in different parts of the image field are easily detected by this technique

An important source of error in this connection is the distortion produced by the image intensifier This arises partly from a non parallel roentgen beam and partly from the fact that the primary screen of the image intensifier is not plane but slightly convex As a result, the so-called pincushion effect is produced, i e a square is not reproduced as a square but as a cushion like figure with the sides of the square bulging slightly inwards In addition to this general distortion in the image intensifier, which results in an error in image recording increasing symmetrically from the centre towards the periphery, irregular distortions often also occur in the image intensifier, even in the centre of the image field Careful adjustment of the electron-optical system of the image intensifier can reduce these aberrations to a minimum and to such an order of magnitude that they have no practical importance for the measurements in question Irregularity of form of the image due to pincushion distortion cannot be compensated in a simple way Recording of the image of a wire network with square meshes of known dimensions, and correction of every coordinate

on the image by this means would be a conceivable but time consuming and complicated procedure Measurements on the image intensifier used here have indicated that the distortion in the periphery amounts to about 10 %

The entire field of the image intensifier was never utilized in the present investigations, however Only the central part, with a diameter of about 12 cm, was usually used, the maximal deviations of this central image field from the ideal image amount to less than 1 % The error amounts to 4 % about 2 cm outside this central image field and then increases rapidly to 10 % at the periphery This means in practice that this error in image recording may be ignored for normal-sized and moderately enlarged left ventricles Only for the very large end-diastolic volumes of the left ventricle does this error in image recording bear any importance, it may then give excessively large diastolic volumes and consequently too high values for the stroke volume as well

The decreasing resolving power of the image intensifier from the centre and out towards the periphery meant no problem in this study The resolving power in the part of the image field utilized was high enough on all occasions to allow good delimitation of the contrast-filled left ventricle from its surroundings The exposure rate used in the film camera was 40 per second, which was the highest rate with the present equipment Theoretically it may be accepted that an exposure frequency of 25 per second should be a sufficiently high sampling rate to capture most of the courses in the activity of the heart, the exposure rate of 40 per second should thus give satisfactory demonstration of most of them It is clear, however, that certain events in the heart, especially at the beginning and end of systole and diastole, have a frequency of up to 100 to 200 periods/second Thus, in order to study these courses in detail, high exposure frequencies are desirable This means, among other things, that the use of a TV system in place of cinefilm would be impossible, since TV systems have a maximal exposure rate of 50/second (or 60/second) The value of studying such rapid courses must, however, be weighed against the greatly increased number of data obtained for analysis at high exposure frequencies compared with those at moderate frequencies, such as the 40/second used here Factors such as installation costs, costs per examination and roentgen dose to the patient per examination must also be considered

The contrast injection with a volume of about 15 to 20 ml/second into the left atrium or left ventricle may conceivably influence the volumes of the cardiac chambers and even the function of the heart SANMARCO et coll (1966) working with dogs reported an increased end-diastolic volume and a raised stroke volume during the first three beats in association with the injection of contrast medium into the left ventricle By avoiding if possible the use of the first three beats after the injection for measurements, and by as far as possible

making the injection into the left atrium instead of the left ventricle, this effect may be largely avoided The more marked changes in the haemodynamics that appear after the injection of contrast medium, in the form of increased cardiac output and rate, and decreased blood pressure, occur later in the course and need not, as a rule, influence measurements of the left ventricular volume on injection into the left atrium or left ventricle This effect may on the other hand influence the measurements if the injection is given intravenously or into the right side of the heart

One prerequisite for satisfactory functioning of the formula used for calculation of the left ventricular volume is that the longitudinal axis and largest projection of the ventricle are recorded in a plane perpendicular to the central beam in the image recording system Experience has established that with the guidance of the catheters, the position of the patient can be adjusted so that the greatest projection of the left ventricle lies in or near to the horizontal plane when he is recumbent Minor deviations from the ideal position are, of course, unavoidable The importance of such deviations has been studied with the aid of plasticine models of left ventricles of various sizes These studies disclosed that deviations of up to 10° from the ideal position in the plane were of no importance for the size either of the projected area or of the longitudinal axis. Deviations of 15° gave an area and longitudinal axis about 4 % smaller than the true dimensions, and deviations of 20° produced differences of up to 8 % in these measurements. Recording in two planes has indicated that no deviations of more than 10° from the ideal position of the left ventricle occur The variations in the position of the left ventricle that occur during the cardiac cycle are small and not of such an order of magnitude as to influence the measurements in question

It is important in the calculation of the magnification that the ruler with millimeter markings is placed in the same position and on the same plane as the left ventricle This can be done with a deviation of about 1 cm with the guidance of the position of catheters and other landmarks This means that an error of ± 3 % in the calculated volumes can occur To reduce this error it is necessary for the position of the ruler to be set even more carefully with the aid of fluoroscopy with a horizontal beam

As mentioned previously the mathematical formula used for calculating the left ventricular volume, based on a projection of the left ventricle, has proved to be well correlated to the true volume (DAVILA & SANMARCO 1966) These authors stated that the correlations between the true and calculated volumes were practically as good with this procedure as with the two-plane system The advantage of employing only one plane is again the smaller number of data that need to be analysed in comparison with the two-plane procedure One

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special difficulty arises when the contractions of the left ventricle are no longer symmetric, as they usually are This occurs, for example, in residual conditions after myocardial infarction If a high-degree deformation of the lumen and contraction pattern of the ventricle has occurred, the mathematical formula is, of course, no longer completely valid But the fact that in the described mathematical formula the area worked, which in itself involves an integration, the source of error is also smaller than if only diameters were worked Similarly, several injections of contrast medium may make it possible to arrive at that projection of the left ventricle which completely encompasses the immobile or abnormally contracting part of its wall This means that the appearances of the ventricle have again been brought closer to those of the imaginary mathematical model

An important source of error lies in the establishment of the coordinates for the left ventricular volume, i e in the reliability and constancy with which the contour of the left ventricle can be followed when it is projected in the recording coordinate system A good result necessitates that the cinefilm obtained should be of high quality, with as high definition as possible and with relatively high contrast, all this facilitates the delimitation of the contrast-filled left ventricle A further requirement is an experienced observer with a good knowledge of anatomy who can make the necessary anatomical demarcations The reliability of the results was studied by double determinations made by two observers simultaneously at an interval of three weeks The constancy in delimitations of the contour of the left ventricle, and thereby in the establishment of the coordinates, was found to be satisfactory, and the volume curves for the left ventricle presented good agreement from the two different determinations (Fig 6) Differences in the volume curves from the two determinations occurred especially in diastole These on analysis proved to be due to some inconstancy in the demarcation of the left ventricle from the likewise contrast-filled aorta

It should be pointed out that the procedure described for the construction of volume curves and pressure-volume curves, and subsequent computer analysis of these curves, is based entirely on primary material which is being collected at present in connection with investigations of cardiac patients The patients will not therefore be troubled by further diagnostic measures, and no further claims need to be made on hospital resources The technique used means a new way of analysing and presenting information which otherwise is 'concealed' among the large number of data collected at cineangiocardiography with simultaneous pressure recordings The extra apparatus required consists of an arrangement for synchronization of roentgen cinefilms and pressure recordings (The cost of such an arrangement would amount to about 2 000 Swed Kr )

The costs of plotting the cineangiocardiograms from the left ventricle and

the subsequent computer analysis have been estimated to be about 200 Swed Kr per patient in a current test series of 30 patients With routine use of this procedure this cost could probably be reduced considerably and the total cost of an analysis of this kind would perhaps lie between 100 and 150 Swed Kr The total cost of the investigation of a cardiac patient in a special clinic with heart catheterization and angiocardiography is not known but may be estimated to between 2 000 and 3 000 Swed Kr In the light of such costs, the extra expenditure for the computer analysis must be regarded as relatively small

A considerable portion of the costs for the analyses are connected with the actual plotting work, which at present is performed manually and which, although it can be done fairly quickly in the special plotter, still requires about 30 to 60 minutes per patient This staff demanding and time consuming part of the work may be reduced by using apparatus that allows fully automatic determination of the volume variations of the left ventricle from cinefilms

Preliminary trials have been carried out with a Quantimet Image Analysing Computer (QTM) (Metals Research Ltd, Melbourn, England), which was originally constructed for measurement and counting of particles of different kinds (BJORK & ERIKSON 1969) QTM works with a television scanning system in which areas and figures with certain density levels can be recognized in projected images and their sizes and diameters calculated This apparatus after an adjustment for each cinefilm enables true variations in the left ventricular area as well as variations of the longitudinal axis to be determined automically frame for frame QTM for this purpose must be complemented by an automatic feed for the film and an automatic recording arrangement, e g a tape punch

**Acknowledgement**

The method of construction of volume curves and pressure volume curves and for their further analysis was developed in collaboration with Saab Linkoping Sweden, (Engineer Carl Joelson) This work was supported by a grant from the Swedish National Association against Heart and Chest diseases

## SUMMARY

A technique for the semi automatic construction of volume curves and pressure volume loops from data collected at left ventricular cineangiocardiography, and computerized analysis of these curves have been used in a series of 30 cases Examples of the possibilities of obtaining increased information on the function of the left ventricle with the method are presented

## ZUSAMMENFASSUNG

In einer Serie von 30 Fallen wurden halbautomatische Volumen und Druckvolumen kurven wahrend der Cineangiographie des linken Ventrikels angelegt und mittels einer Daten verarbeitungsmaschine analysiert An Beispielen werden die Moglichkeiten, mehr Information uber die Funktion des linken Ventrikels zur erhalten, illustriert

## RÉSUMÉ

L'auteur a utilise dans 30 cas une technique semi automatique de construction de courbes de volume et de diagramme de pression volume a partir des donnees recueillies par cine an giocardiographie du ventricule gauche, et a fait analyser ces courbes par ordinateur Il donne des exemples dans lesquels cette methode a permis d obtenir plus d informations sur la fonc tion du ventricule gauche

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# PHLEBOGRAPHIC CHANGES IN ARTERIOMEGALY

by

M LEA THOMAS and M R ANDRESS

LERICHE in 1943 described in detail a patient with elongation and dilatation of the right common iliac artery simulating an aneurysm At operation, in addition to the dilated and elongated common and external iliac arteries, he found a similarly though less markedly lengthened and dilated common iliac vein which he considered to be of twice normal calibre, there was also dilatation of the origin of the inferior vena cava This author had first drawn attention to the arterial condition a year earlier (LERICHE 1942) and since that time there have been a very large number of descriptions of lengthening, dilatation and tortuosity of arteries at many sites in the body (LERICHE 1947, 1954, LEGER & CERBONNET 1950, HULTEN GYLLENSTEN et coll 1959, BARIETY et coll 1961 CASTEN & FORMAN 1962, WAREMBOURG et coll 1963, ACKERMAN & BUTCHER 1964, STAPLE et coll 1966, ERTUGRUL 1967, ECOIFFIER et coll 1968 BEUREN et coll 1969) but there has been little further mention of venous changes However VILLAR & HOFFMANN MARTINOT (1951) described a case of a tortuous brachial artery in which large superficial veins were noted in the forearm whereas STAPLE et coll (1966) observed that in none of their surgically resected specimens was there any venous enlargement There has been no description of phlebography in this condition

Submitted for publication 26 September 1969



a



b

Fig 1 a) Arteriomegaly b) Pelvic phlebography Normal sized veins with an impression on the outer aspect of the left common iliac vein (arrow) by the left common iliac artery



a



b

Fig 2 a) Arteriogram showing arteriomegaly of the iliac and femoral arteries b) Normal pelvic phlebography

LERICHE called this condition 'dolicho et mega artere, dolicho et méga-veine' The name most commonly used by other authors has been dolicho-*mega artere* but some have called it arteria magna et dolicho of Leriche, arteriectasis, and buckling or kinking of arteries We suggest the term arteriomegaly as being simple and purely descriptive as the aetiology of the condition is not clearly defined

*Material and Methods* In sixteen patients with the radiologic features of arteriomegaly, phlebography of the accompanying veins was performed Twelve of the patients were being investigated for intermittent claudication but in addition had features such as swelling or ulceration of the ankles or varicose veins for which examination by phlebography was considered necessary

The four other patients were being investigated for probable obstruction of the venous system and phlebography showed defects in the veins suggesting pressure from glands, or thrombosis, arteriography was then performed to prove that such abnormalities were in fact due to pressure from adjacent enlarged arteries

In nine cases, impressions on the iliac veins were observed In one case only, phlebography of the lower limb was performed

The arteries were examined by translumbar aortography in the prone position in twelve patients, and by the percutaneous catheter technique in the supine position in the remaining four Pelvic phlebography was performed by percutaneous bilateral femoral vein catheterisation and the films taken with the patients in the same position as for the arteriography Peripheral lower limb phlebography was performed by our usual technique (BROWSE et coll 1967, 1968) In all instances the position of the patient, prone or supine, and the field covered by the films, were identical for both arteriography and phlebography

## Discussion

In none of the sixteen patients examined by phlebography was there enlargement or elongation of the corresponding veins as described by LERICHE

No phlebographic standards have been established for the normal size of the veins of the pelvis or legs and we did not consider it would be ethical to carry out phlebography in symptomless patients to obtain measurements of this type However, we considered that the size of the veins in these sixteen patients was within the normal range as judged by the several hundred phlebographic examinations which we have carried out on the pelvic and leg veins (COCKETT et coll 1965, 1967, BROWSE et coll 1967, 1968, 1969, LEA THOMAS et coll 1967, FLETCHER & LEA THOMAS 1968)



a



b

Fig 3 a) Arteriomegaly b) Pelvic phlebography Impression in the right external iliac vein (arrow) by the right external iliac artery



a



b

Fig 4 a) Arteriomegaly b) Pelvic phlebography Large filling defect in the left common iliac vein (arrow) caused by the left common iliac artery

In nine of the sixteen patients there were indentations (Figs 1, 2, 3) in the venous system by neighbouring arteries Such impressions may be caused even by normal arteries (BARTLEY 1958, LEA THOMAS et coll 1968) but because of the enlargement and tortuosity in arteriomegaly these impressions are sometimes of considerable size (Fig 4)

These arterial impressions or indentations do not accord with the description of the widening and dilatation of the right common iliac vein and inferior vena cava given by LERICHE It is possible, however, that a high partial obstruction of the inferior vena cava by the dilated right common iliac artery might have caused the appearances although he does not suggest this in his paper Alternatively, a primary venous disease may have been present

Two of our patients had venous occlusions, probably unrelated to the arteriomegaly, one due to past deep venous thrombosis and the other from retroperitoneal fibrosis

## Acknowledgements

We wish to thank Mr N L Browse, Mr F B Cockett, and Prof J B Kinmonth for permission to publish the results of investigations performed on their patients We should also like to thank Mr T W Brandon of the Photographic Department St Thomas Hospital, for reproducing the illustrations

## SUMMARY

The phlebographic findings in sixteen patients with arterial lengthening and dilatation are presented None had dilatation or elongation of accompanying veins as described by LERICHE (1943) Impressions on veins by enlarged arteries were observed in nine patients The term arteriomegaly is suggested for the arterial condition described by LERICHE (1942) and others

## ZUSAMMENFASSUNG

Die phlebographischen Befunde von sechzehn Patienten mit einer arteriellen Verlangerung und Dilatation werden dargestellt Keiner der Patienten hatte eine Dilatation oder Verlangerung der begleitenden Venen wie sie von LERICHE (1943) beschrieben worden sind Bei neun Patienten wurde eine Einbuchtung der Venen durch die anliegenden vergrosserten Arterien gefunden Der Ausdruck Arteriomegalie wird fur die von LERICHE (1942) und anderen beschriebenen arteriellen Veranderungen vorgeschlagen

## RÉSUMÉ

Les auteurs decrivent les images phlebographiques chez seize malades presentant des allongements et des dilatations des arteres Aucun n avait de dilatation ou d allongement des veines satellites comme LERICHE en avait decrit (1943) Chez neuf malades les arteres voisines dilatees marquaient leurs empreintes sur les veines Les auteurs proposent le terme d arterio megalie pour designer l etat arteriel decrit par LERICHE (1942) et par d autres

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# DIAGNOSIS OF FLUID IN THE MAXILLARY SINUS

by

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Maxillary sinusitis is demonstrated radiographically as thickening of the mucous membrane and often by the presence of fluid Since the occurrence of fluid is considered to require irrigation, a high degree of diagnostic accuracy is necessary Essential conditions for the demonstration of fluid are that air is present and that a horizontal beam be used The frequency of fluid has been investigated at irrigation in radiographically demonstrated sinuses (BALLANTYNE 1946, BUCH 1949, VUORINEN et coll 1962) It was found to occur in 65 % to 88 % of the pathologic sinuses BALLANTYNE and BUCH probably did not use a horizontal beam and subsequently could not demonstrate fluid VUORINEN et coll employed a horizontal beam but failed to report the frequency of fluid demonstrated at the radiologic examination

The aim of the present investigation was to determine the frequency of fluid in the maxillary sinuses demonstrated radiographically as well as by irrigation, in order to establish the diagnostic reliability of the radiologic demonstration of fluid

*Material and Methods* The series comprised 197 patients, 113 females and 84 males aged 3 to 74 years (mean 31 years) There were 301 maxillary

Submitted for publication 30 August 1969



Fig 1 Right maxillary sinus a) Erect Thickened mucous membrane but not definite fluid level b) Right recumbent position The outline of the air space has changed indicating the presence of fluid

sinuses, 152 on the right and 149 on the left side, with pathologic changes demonstrated radiographically

All the patients were examined sitting at the Lysholm skull table with the central beam horizontal The following four standard projections were used (1) occipitofrontal, (2) occipitomental, (3) full axial, and (4) lateral There were 61 patients in whom 88 sinuses presented mucous membrane thickening



Fig 2 Right maxillary sinus a) Erect Soft tissue mass with oblique surface caudally b) Right recumbent position The fluid level is now clearly seen

**Table 1**

*Frequency of fluid demonstration at irrigation of the maxillary sinuses*

| | Total sinuses | Fluid demonstrated | |
|---|---|---|---|
| | | Number | Per cent |
| Sinuses containing at least some air | 210 | 128 | 60 |
| Sinuses without air | 83 | 71 | 86 |
| Sinuses with cysts or polyps | 8 | — | — |
| Total | 301 | 199 | 66 |

**Table 2**

*Frequency of fluid in maxillary sinuses containing some air demonstrated on irrigation and at roentgen examination*

| Type of radiographic examination | Width of mucosal membrane thickening in mm | Number of sinuses | Sinuses with fluid on irrigation | | Sinuses with fluid at roentgen examination | | Radiologic confidence level, in per cent |
|---|---|---|---|---|---|---|---|
| | | | Number | Per cent | Number | Per cent | |
| The four standard projections | 1—6 (group A) | 108 | 59 | 55 | 10 | 9 | 17 |
| | >6 (group B) | 102 | 69 | 68 | 21 | 21 | 30 |
| Total | | 210 | 128 | 61 | 31 | 15 | 24 |
| The four standard projections plus the fifth projection and affected side down | 1—6 (group A) | 30 | 19 | 63 | 16 | 53 | 84 |
| | >6 (group B) | 34 | 24 | 71 | 20 | 59 | 83 |
| Total | | 64 | 43 | 67 | 36 | 56 | 84 |

but still contained some air, and in whom none of the four standard projections disclosed any fluid, a fifth projection was added, the occipitomental with the head horizontal. Of the eighty-eight sinuses, sixty four were examined with the affected side downwards and twenty-four with the affected side up. Examinations in the fifth projection and in the full axial projection are facilitated by supporting the head on a shelf attached to the skull table as described by TURESSON (1948).

**Table 3**

*Frequency of fluid in maxillary sinuses containing air demonstrated at irrigation and at roentgen examination in the four standard projections*

| Width of mucosal thickening in mm | Number of sinuses | Fluid demonstrated on irrigation | | Fluid demonstrated at roentgen examination | |
|---|---|---|---|---|---|
| | | Number | Per cent | Number | Per cent |
| 1—3 | 32 | 13 | 41 | 2 | 6 |
| 4—6 | 76 | 46 | 61 | 8 | 11 |
| 7—9 | 43 | 28 | 65 | 6 | 14 |
| 10—12 | 32 | 21 | 66 | 11 | 34 |
| >12 | 27 | 20 | 74 | 4 | 15 |

The width of the thickened mucous membrane was measured at the middle part of the lateral sinus wall Fluid was considered to be present when a level was seen in one or more standard projections The presence of fluid was demonstrated in the fifth projection by comparing the outline of the air space in the sitting and recumbent positions (Figs 1 and 2) All the sinuses were irrigated within half an hour after the roentgen examination Where no fluid was demonstrated in any of the five projections, but was revealed on irrigation, its amount was noted

## Results

Fluid was demonstrated at irrigation in 66 % of the 301 sinuses of the series that had been found radiographically to be pathologic (Table 1) It was present in 86 % of the sinuses devoid of air, and in 61 % of the sinuses with mucosal thickening but still containing some air Eight sinuses devoid of fluid on roentgen examination or when irrigated, contained a cyst or polyp

Sinuses containing at least some air were divided into two groups (Table 2) Group A consisted of those with mucosal thickening of from 1 to 6 mm and group B of those with more than 6 mm thickening Fluid was demonstrated with the four standard projections in 9 % and in 21 %, respectively, in the cases of groups A and B, and on irrigation in respectively 55 % and 68 % The difference in the radiologic diagnosis between the groups is statistically significant The figures correspond to a radiologic confidence level of respectively 17 % and 30 % in the two groups

The sinuses were further divided into groups with different degrees of




Fig 3 Left maxillary sinus a) Erect Two soft tissue masses the larger one (—→) concave upwards at the sinus walls b) Left recumbent position The lesser tissue mass (+→) is unchanged indicating mucosal swelling the larger one (—→) has moved to the lateral part of the sinus and changed in shape viscid fluid obtained at irrigation

mucosal membrane thickening, and the radiologic findings were again correlated to the irrigation results The frequency of obtaining fluid at irrigation rose with an increasing degree of mucosal thickening (Table 3) However the radiologic confidence level for fluid demonstrated by the standard projections increased only up to a mucosal width of 12 mm and decreased at higher values.

Fluid was demonstrated radiographically and confirmed by irrigation in 56 % and 67 %, respectively, of the sixty four sinuses examined with the fifth projection and the affected side down (Table 2) This corresponds to a radiologic confidence level for fluid demonstration in groups A and B of respectively 84 % and 83 % When the maxillary sinuses with fluid demonstrated by the standard projections were added, the confidence levels for groups A and B increased to 87 % and 88 %, respectively (standard deviation 4 %) In four cases fluid was demonstrated on irrigation, but not radiographically in the fifth projection with the affected side down, the amount of fluid in these cases did not exceed 5 ml The twenty four sinuses examined with the fifth projection but with the affected side up had a radiologic confidence level of fluid demonstration of 50 % The difference between the results obtained with the affected side directed down and up is statistically significant The fluid presented an upwards concave outline near the sinus wall in all cases except two in which the outline was convex upwards (Fig 3), in both these cases a mucous, viscid fluid was obtained on irrigation No statistical difference was recorded



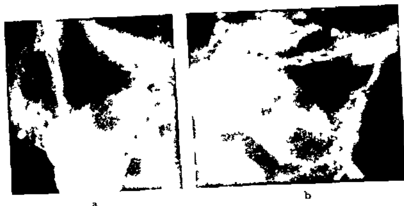

Fig. 4. Left maxillary sinus. a) Erect. Soft tissue mass caudally with horizontal outline and convex upwards at the sinus walls (arrow). b) Left recumbent position. The mass represents a soft mobile polyp with a narrow pedicle (arrow).

as regards fluid demonstrated in women and men or between the right and left maxillary sinuses.

## Discussion

Fluid levels in an antrum are readily disclosed in standard projections when the amount of fluid is considerable but may be absent when the amount is small. The present investigators failed to demonstrate fluid in about three quarters of the sinuses containing air. The reason may have been that small levels were present at the bottom of the sinus, which are often concealed by the alveolar process and by the teeth. As TURESSON pointed out, a fluid level in the frontal sinuses may be demonstrated in an occipitofrontal projection with the head horizontal and one side down, while a level in the sphenoidal sinuses should be demonstrated in the lateral projection with the head horizontal and the back of the neck down. To increase the confidence level for demonstration of fluid in the maxillary sinuses the occipitomental projection with the head tilted in one or both directions should be employed (HODGSON 1931). Small amounts of fluid in the maxillary sinuses have been demonstrated in an occipitomental projection with the head horizontal and one side down (CLAUS 1926, SAMUEL 1953). No investigation appears however to have been published previously regarding the frequency of fluid diagnosed radiologically by the latter or any other method.

The interval between the roentgen examination and the irrigation has in



a b

Fig 5 Left maxillary sinus a) Erect Mass caudally with a horizontal out ... [illegible] ...bent position The ... [illegible] ... appearance, and [illegible]

previous papers either not been stated or has amounted to several days. A high degree of agreement between the radiologic and the irrigation findings was established in the present investigation by the fact that all the irrigations were made within half an hour of the roentgen examination

Fluid was produced at irrigation in 88 % by BALLANTYNE, in 65 % by BUCH, in 77 % by VUORINEN et coll and in 66 % of the maxillary sinuses with radiographic changes in our series. The differences probably depend on a higher frequency of sinuses with a minor degree of mucosal thickening in our material and in BUCH's as compared with the other two series. The frequency of fluid is lower in such sinuses than in those with more marked mucosal thickening

It was found in the present investigation that the radiologic confidence level for the demonstration of fluid in maxillary sinuses containing at least some air was 24 % where the four standard projections were concerned When the examination was extended with the occipitomental projection, with the head in horizontal position and the affected side down, the diagnostic confidence level increased to 88 % Some of the diagnostic difficulties at examinations with the affected side up may depend on the irregular shape of the medial maxillary sinus wall and the fact that the posterior ethmoidal cells partly conceal the medial aspect of the maxillary sinus. These facts may explain why small differences in the outline of the air space are easier to detect in the lateral than in the medial part of the sinus

In the two maxillary sinuses containing a mucous, viscid liquid, the fluid level near the sinus walls had an upwards convex outline A similar appearance




Fig. 4. Left maxillary sinus. a) Erect. Soft tissue mass caudally with horizontal outline and convex upwards at the sinus walls (arrow). b) Left recumbent position. The mass represents a soft mobile polyp with a narrow pedicle (arrow).

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# ELIMINATION OF BLUR IN LINEAR TOMOGRAPHY

by

PAUL EDHOLM and LARS QUIDING

The interpretation of the diagnostic content of a linear tomogram is complicated by the presence of *blur* This is the main reason for other types of tomography being preferred, where practicable, as for instance those based on circular and hypotrochoidal motion in which the blur is less marked Linear tomography possesses however the advantages that the apparatus *is inexpensive* and simple in design, that a high level of precision can be obtained and that the exposure times are short, the ordinary roentgen unit can moreover often be adapted for linear tomography As linear tomography is the only *practicable* technique in neuroradiologic examinations requiring *certain* projections, a method of eliminating blur from linear *tomograms* seems to be urgently *needed*

*Linear blur* A tomogram consists in the main of *two* groups of components, the details in the tomographic layer and those *outside it* (Fig 1a) The former are sharp whereas the latter are *blurred in the* direction of *motion, so* that the contrast is reduced to a point where *details* usually *cannot* be perceived Certain details are resistant however and remain visible as long stripes with

Submitted for publication 17 December 1969

may however also represent a soft polyp or a cyst containing fluid under low tension With the fifth projection added, the observation of a change in shape and position of the air is often useful for a differentiation between viscid fluid polyps and cysts (Figs 3, 4 and 5)

It is interesting to note that in the material of VUORINEN *et coll*, *fluid* was disclosed on irrigation in 6 % of the radiographically normal maxillary sinuses To judge by the findings in our investigation, those fluid contents could probably have been demonstrated *with the fifth* projection It thus appears that the occipitomental projection with the head horizontal and the affected side down can be recommended as a routine when the mucous membrane is thickened and some air remains and when the standard projections have not disclosed any fluid

## SUMMARY

The frequency of fluid in the maxillary sinuses demonstrated at roentgen examination in a material of 197 cases is recorded The method of showing the fluid levels its confirma *tion by* irrigation, and the differential diagnosis are discussed at length

## ZUSAMMENFASSUNG

Die Frequenz der Nachweisbarkeit von Flussigkeit in den Oberkieferhohlen wurde bei Rontgenuntersuchungen von 197 Fallen festgestellt Es wird detailliert erortert wie die Flussigkeitsspiegel am besten demonstriert werden konnen, auch anhand der Kieferspulung Die Differentialdiagnose wird diskutiert

## RÉSUMÉ

Les auteurs ont note sur 197 malades la frequence des signes radiologiques d epanchement liquide dans les sinus maxillaires Ils étudient assez longuement la méthode pour mettre en évidence le liquide pour confirmer sa presence par lavage et examinent le diagnostic differentiel

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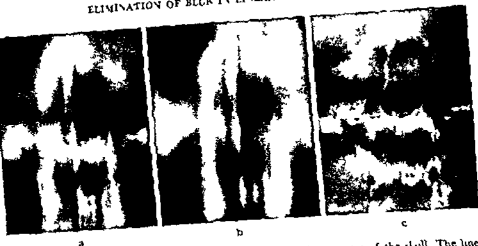



Fig 2 Photographs of the television monitor with a frontal tomogram of the skull The lines of the television image are vertical a) Untreated tomogram. b) Duplicate of the tomogram after passing through the low pass filter c) Difference image of (a) and (b)

eliminates the sharp details while leaving the stripes almost unchanged The copy will thus be a negative of the linear blur, and when it is placed on the tomogram the stripes in the two films will cancel each other out The sharp details in the tomogram have no counterparts in the copy and will therefore be reproduced as before but undisturbed by linear blur

The displacement of the contact copy during exposure calls for precision, and is not easily done manually An apparatus for effecting this smoothly and under control has therefore been designed and constructed The most suitable displacement distance has been found to be about 2 cm

If the tomogram contains linear blur in areas differing greatly in density the blur will be underexposed in some parts of the copy and incompletely eliminated when the copy and tomogram are superimposed The tomogram should then be combined first with a negative having multidirectional blur The contrast is evened out in this manner so that in the final copying the exposure will be approximately the same for all the blur (Fig 1b) All the stripes can then be reproduced in the copy and completely eliminated

*Sharp copy* With this method an ordinary sharp negative copy of the tomographic film is produced Both images will thus contain sharp and blurred details and if they are combined in the usual way a uniformly grey image will result If the copy and the tomogram are displaced a short distance in relation to each other, in the direction of the stripes, the sharp details will again be seen, though they will not have the usual appearance but give the impression

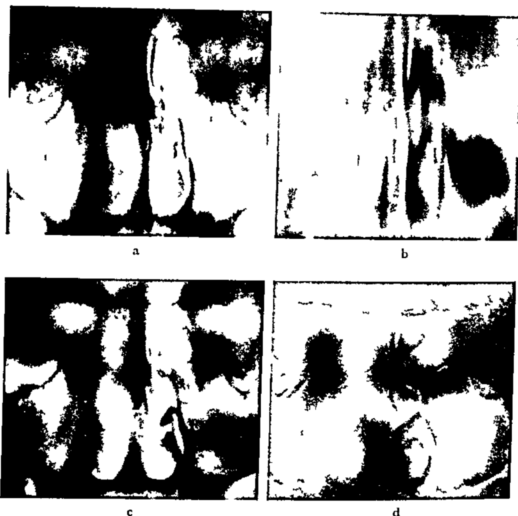



Fig 1 Carcinoma of the right maxillary sinus with destruction of the medial wall a) Tomogram b) Copy with linear blur in which the contrast has been evened out c) Combination of (a) and (b) d) Combination of (a) and a sharp copy displaced in the direction of the linear blur

diffuse ends and sharp lateral contours parallel to the direction of motion The resistance of detail to blurring is dependent on its contrast and its dimension in the direction of motion

*Photographic methods* Photographic methods of eliminating blur are based on subtraction, a transparent contact copy of the tomogram being subtracted from the tomogram itself Two methods will be described

*Copy with linear blur* Blur is produced in a contact copy by moving it in the direction of the stripes at a constant speed during the copying process This

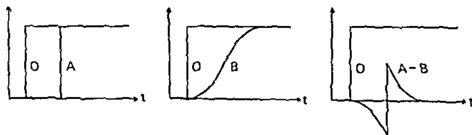



Fig 5 Appearances of the signal at the various points in fig 4 0 — untreated A — delayed, B — after passing through a low pass filter, A—B = subtraction

of this derivative, while the stripes have low values Areas with positive and negative derivatives are reproduced in light and dark, respectively, while areas where the derivative is zero are reproduced as a neutral grey

The optimal displacement between copy and original has been found to be a little less than one millimetre The results were poorer than with the former method, the image being ill defined and difficult to interpret in the direction of displacement

*Electronic methods* A television image is composed of lines that are scanned in succession and can thus easily be modified in the direction of the lines. If a tomogram is placed in front of a television camera, with the stripes parallel to the scanning lines, the sharp image details will give high frequencies in the television signal while the blur will produce low frequencies This fact affords several possibilities of eliminating the linear blur by means of filters Three methods will be described

*Subtraction with two cameras* The tomogram is placed under one camera and a duplicate of the tomogram under the other camera The films are orientated so that the stripes run parallel to the lines of the television image The signal from one camera is passed through a filter that eliminates the high signal frequencies and leaves the low frequencies unaffected, the sharp details are thus eliminated and the stripes remain unchanged This signal, which now consists chiefly of blurred detail, is subtracted from the unfiltered signal produced by the other camera The filter incurs a time delay, and this is compensated for by moving one of the images over a corresponding distance parallel to the lines of the television image The difference signal produces an image of only the sharp details — the stripes are eliminated The procedure is illustrated in Fig 2 Two disadvantages of this two-camera method are its complicated

a b

*Fig 3 Images from the monitor in the same case as in fig 1 a) Untreated tomogram b) After passing through a high pass filter*

of a relief viewed by oblique illumination The stripes, on the other hand, because their ends are diffuse, will not be seen at all (Fig 1d)

This method gives in effect the derivative of the density relief in the direction of the displacement The sharp details have high positive and negative values

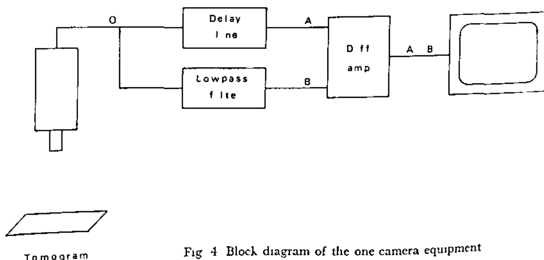



Fig 4 Block diagram of the one camera equipment

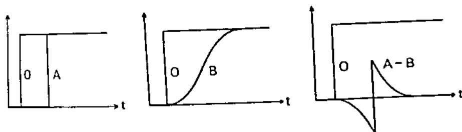



Fig 5 Appearances of the signal at the various points in fig 4 0 — untreated, A — delayed, B — after passing through a low pass filter, A—B = subtraction

of this derivative, while the stripes have low values Areas with positive and negative derivatives are reproduced in light and dark, respectively, while areas where the derivative is zero are reproduced as a neutral grey

The optimal displacement between copy and original has been found to be a little less than one millimetre The results were poorer than with the former method, the image being ill defined and difficult to interpret in the direction of displacement

*Electronic methods* A television image is composed of lines that are scanned in succession and can thus easily be modified in the direction of the lines. If a tomogram is placed in front of a television camera, with the stripes parallel to the scanning lines, the sharp image details will give high frequencies in the television signal while the blur will produce low frequencies. This fact affords several possibilities of eliminating the linear blur by means of filters Three methods will be described

*Subtraction with two cameras* The tomogram is placed under one camera and a duplicate of the tomogram under the other camera The films are orientated so that the stripes run parallel to the lines of the television image The signal from one camera is passed through a filter that eliminates the high signal frequencies and leaves the low frequencies unaffected, the sharp details are thus eliminated and the stripes remain unchanged This signal, which now consists chiefly of blurred detail, is subtracted from the unfiltered signal produced by the other camera The filter incurs a time delay, and this is compensated for by moving one of the images over a corresponding distance parallel to the lines of the television image The difference signal produces an image of only the sharp details — the stripes are eliminated The procedure is illustrated in Fig 2 Two disadvantages of this two camera method are its complicated

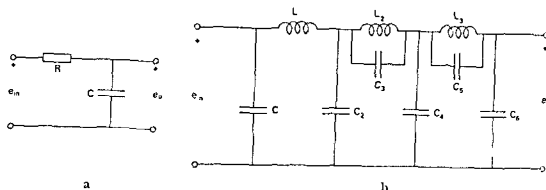



Fig 6 a) A simple low pass filter b) The Thomson low pass filter

nature — the tomogram must be duplicated — and the fact that the equipment is expensive

*One camera with a high pass filter* A high pass filter inserted in an ordinary television circuit for transmission of roentgenograms damps low signal frequencies, whereas the high frequencies are unaffected, that is to say, the linear blur is reduced and the sharp details are unchanged To eliminate blur completely with a simple high pass filter, a filter that will let pass only the highest signal frequencies must be chosen A contour image in which it is difficult to relate the contours to the anatomic details will then be obtained (Fig 3)

This procedure is simple, all that is required apart from the adjustments normally performed in the TV transmission of ordinary roentgenograms is that the tomogram should be placed so that the stripes become parallel to the lines of the television image

*One camera with low pass filter and delay line* The simplicity of the one camera procedure may be combined with the good image quality of the two camera method as is schematically illustrated in Fig 4 The signal from the television camera is fed to two circuits in parallel, in one of which the sharp details are eliminated by a low pass filter that surpresses the high frequencies and leaves the stripes unchanged In the other circuit the signal passes untreated through a device that delays it for the time that the other signal is held up by the filter, the correct time relationship between the two signals is thus retained The filtered signal is then subtracted from the delayed signal A sharp contour in the tomogram gives rise to signals as in Fig 5, where (O), (A) and (B) are the signals from the television camera, the delay circuit and the filter, respectively, and (A—B) is the signal seen on the television monitor In the elimination of the linear blur, the choice of filter is not a particularly

critical factor, whereas the reproduction of the sharp details is largely dependent on the properties of the filter. The desired sigmoid output signal in Fig. 5 B can be produced sufficiently accurately via a series of filters connected in cascade as in Fig. 6a, or by a Thomson filter as in Fig. 6b.

## Discussion

The part of the body depicted in a tomogram may be regarded as consisting of a number of parallel layers, one of which is the tomographic layer. The tomogram is a summation of all these layers. The tomographic layer is fully defined, but the other suffer loss of their high spatial frequencies. It appears as if all the layers, except the tomographic one, pass through a filter that only transmits low frequencies. The greater the distance between the tomographic layer and any other layer, the greater the lost frequency range.

Tomography may be regarded as a method that provides a selective picture of the tomographic layer by filtering out the rest of the body, the effect is incomplete, however, because only the high frequencies are suppressed, the low frequencies being represented as blur.

In effect, both the methods that have been described for eliminating linear blur, the photographic and the electronic, amount essentially to refiltering the tomogram so that the high frequencies are unmodified and the low frequencies are suppressed. This results in total elimination of the undesirable layers and isolation of the tomographic layer. The low frequencies in this layer are however also filtered out. The effect of this will be that any true detail in the tomographic layer, with form and position similar to a tomographic stripe, will disappear. For this to happen, the detail must however be exactly aligned with the direction of tomographic motion.

## SUMMARY

Various methods of eliminating blur in linear tomography are discussed. Television circuits which include filters passing high frequencies and suppressing the low frequencies that cause the blur are described.

## ZUSAMMENFASSUNG

Versuche wurden angestellt, um zu ermitteln wie Unscharfe bei linearer Tomographie vermieden werden kann. Es wurden Fernsehketten mit Filtern benutzt die Hochfrequenzen passieren lassen und die die Niedrigfrequenzen die Unscharfe verursachen, unterdrucken.

## RÉSUMÉ

Les auteurs examinent les differentes méthodes qui eliminent le flou en tomographie lineaire. Ils décrivent des circuits de television comprenant des filtres laissant passer les hautes frequences et arrêtant les basses frequences qui causent le flou.

## Book review

DOSAGE NON DESTRUCTIF DE LA COMPOSANTE MINÉRALE DU TISSU OSSEUX PAR DENSITOMÉTRIE RADIOGRAPHIQUE Par W Mouvet Éditions Arscia, Bruxelles 1967

This book is another approach to the difficult problem of radiographic determination of mineral content of bone The author has thoroughly analysed the physical phenomena involved, and the detailed introduction deals with the absorption of roentgen rays, film emulsion and the theory of densitometry The effect of the non random distribution of absorbing components as a potential source of error (ORNSTEIN, Lab Invest 1 (1952), 250) has not been mentioned, but because of the relatively small focal spot, this error probably does not affect the results of the present method

The author uses a special stand consisting of two parallel plates for radiography of the bones The fine-grain nonscreen roentgen film, the reference systems and an aluminium exposure control plate are placed on the lower one The upper plate is made up of a wooden frame, lead bars embedded in perspex and a removable lid The amount of secondary radiation can be assessed with the aid of the lead bars The mineral content of the bone to be examined is expressed as the mean thickness of aluminium, corrections being made for secondary radiation and taking the thickness of the bone and the surrounding soft parts into account The result calculated gives the mineral content of a bone measured transversely in a tracing path

The series examined by the author consists of humeri, radii, ulnae, scaphoids and finger phalanges The bones were sliced according to the densitometric tracing paths, and the results of densitometry compared with those of a chemical analysis A significant statistical correlation was established

The organic fraction and water in the bone tissue usually represent more than half of its weight and vary considerably according to age As pointed out by OMNELL (1958) the ratio between the amount of bone salt per unit of area and the equivalent amount of reference material (aluminium) is dependent on the ratio between the weights of bone salt and organic material and water This is a severe handicap affecting all radiographic methods in which heterogeneous radiation is used The procedure employing almost monochromatic $^{125}$I radiation (CAMERON et coll, Science 142 (1963), 270, Invest Radiol 3 (1968) 141) is theoretically more satisfactory and apparently gives more reliable results (MAZESS et coll, Science 145 (1964), 388)

A bone is a biologic as well as a human skeleton unit and measurements made along a certain tracing path of a bone do not necessarily dependably reflect the mineral content of the bone in question or that of the entire skeleton (HELELA & VIRTAMA, Invest Radiol 3 (1968), 103) Measurements should therefore be made along numerous tracing paths of different bones which makes the densitometric method cumbersome and time consuming The measurement of the cortical bone (VIRTAMA & HELELA, Acta radiol (1969) Suppl No 293) may in the comparison of relatively large groups of population and in clinical studies furnish a practical alternative to more accurate but tedious densitometric methods The choice of the procedure to be used depends on the special problem to be examined in each individual case

The book is well-written and gives a good survey of the factors affecting the densitometric determination of the mineral content of bone It can be recommended as a reliable guide to the special problems involved in radiographic measurement of bone minerals The method presented is certainly suited, e g for control investigations of individual bones, and may probably also be trusted in comparing the mineral contents of individual bones

*Pekka Virtama*

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND NORWAY AND SWEDEN

1970

Vol. 10 DIAGNOSIS November

Fasc 6

# EFFECT OF LOCAL INTRAARTERIAL ADMINISTRATION OF BRADYKININ AND HYDERGINE IN OBSTRUCTIVE ARTERIAL DISEASE

by

UNO ERIKSON

The technique in peripheral arteriography is still far from satisfactory The conventional method of catheter insertion and subsequent injection of contrast medium often fails to give good result

The relation between the blood flow and the peripheral contrast filling has been discussed by ERIKSON (1965), who found that a low blood flow was related to poor peripheral filling at arteriography, proposed the use of local arterial injection of vasodilators, and chose bradykinin VOGLER (1953) has recommended intraarterially administered hydergine for obtaining better contrast filling in patients with varicosis. *Bradykinin is an agent with a short decomposition time* while hydergine has a long decomposition time

Contrast filling of the peripheral arteries did *not* always *improve after local* arterial injection of bradykinin in some patients with extensive occlusion of the femoral artery Possibly the transit time was too long and the shunt effect in the thigh, above the occlusion, too strong, so that the concentration of bradykinin in the small arteries of the calf became relatively low and the vessels did not dilate within the short time of action of the bradykinin Another possible explanation

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Submitted for publication 10 December 1969

**Table**

*Measurements of blood flow at rest and after injection of bradykinin and hydergine in twelve patients with arteriographic results indicated by 0, no change, — decreased contrast filling of arteries, and + improved contrast filling — The code for the diagnoses is given under the heading 'Material and Methods'*

| Case | Age | Sex | Diagnosis | | Place of catheter tip | Blood flow at rest ml/100 ml min | |
|---|---|---|---|---|---|---|---|
| | | | Right leg | Left leg | | Right leg | Left leg |
| 1 | 53 | M | 4 | 1 | Aorta | 4 0 | 5 0 |
| 2 | 76 | F | 2 | 4 | Aorta | 3 0 | 2 3 |
| | | | | | Mean | 3 5 | 3 7 |
| | | | | | Range | 3 0—4 0 | 2 3—5 0 |
| 3 | 75 | M | 0 | 0 | Aorta | 6 1 | 6 3 |
| | | | Injected leg | Control leg | | Injected leg | Control leg |
| 4 | 68 | M | 4 | 4 | Femoral art | 1 2 | 0 4 |
| 5 | 52 | M | 1 | 4 | Femoral art | 1 0 | 0 6 |
| 6 | 73 | F | 1 | 1 | Femoral art | 3 0 | 3 5 |
| 7 | 66 | F | 4 | — | Femoral art | 2 2 | 2 1 |
| 8 | 43 | M | 0 | 4 | Femoral art | 3 4 | 2 2 |
| | | | | | Mean | 2 2 | 1 7 |
| | | | | | Range | 1 0—3 4 | 0 4—3 5 |
| 9 | 52 | M | 0 | 0 | Femoral art | 3 6 | 2 2 |
| 10 | 50 | F | 0 | 0 | Femoral art | 4 0 | 1 9 |
| 11 | 26 | M | 0 | 0 | Femoral art | 2 3 | 2 0 |
| 12 | 32 | F | 0 | 0 | Femoral art | — | — |
| | | | | | Mean | 3 3 | 2 0 |
| | | | | | Range | 2 3—3 6 | 1 9—2 2 |

could be diminished reactivity of the resistance vessels to bradykinin due to constant and marked local metabolic vasodilatation

Hydergine (Sandoz AG, Basel) has a longer half-life and is commonly used in the treatment of peripheral blood flow disturbances The hydrated ergot alkaloids dihydroergocornine, dihydroergocristine and dihydroergocryptine have both a vasodilative effect, due to a sympatholytic action, as well as a number of other effects on the vessel walls of vasoconstrictive nature (EICHLER & HEINZEL 1954) The skin temperature is considered to increase after administration of hydergine (FRANK et coll 1956) VOGLER (1953) stated that arteriovenous anastomoses frequently occurred in leg ulcers, they were closed by intraarterial administration

Table (*cont*)

| Maximal change of blood flow in ml/100 ml min after injection of | | | | | | Effects upon the arteriogram from | |
|---|---|---|---|---|---|---|---|
| Bradykinin | | | Hydergine | | | Brady kinin | Hyder gine |
| Right leg | Left leg | Dose µg/min | Right leg | Left leg | Dose mg | | |
| 0 9 | 0 4 | 19 | —1 3 | —1 8 | 0 6 | + | — |
| 2 0 | 0 9 | 17 | —0 2 | 0 | 0 6 | + | — |
| 1 5 | 0 7 | 18 | —0 8 | —0 9 | 0 6 | | |
| 0 9—2 0 | 0 4—0 9 | | —1 3——0 2 | —1 8—0 | | | |
| 13 4 | 24 2 | 10 | —1 3 | —0 5 | 1 2 | + | 0 |
| Injected leg | Control leg | | Injected leg | Control leg | | | |
| 30 8 | 1 0 | 10 | —0 2 | 1 6 | 0 3 | + | 0 |
| 14 4 | 0 2 | 10 | 0 3 | 0 2 | 1 2 | + | — |
| 27 4 | 2 4 | 10 | 0 7 | 0 5 | 0 6 | + | — |
| 0 | 0 | 10 | 0 2 | —0 7 | 0 6 | 0 | — |
| 18 4 | —0 2 | 10 | —0 4 | —1 5 | 0 6 | + | — |
| 18 2 | 0 7 | 10 | 0 2 | 0 | 0 6 | | |
| 0—30 8 | —0 2—2 4 | 10 | —0 4—0 7 | —1 5—1 6 | 0 3—1 2 | | |
| — | — | 10 | — | — | 0 9 | + | — |
| 0 2 | —0 2 | 30 | —0 8 | —0 6 | 0 6 | 0 | 0 |
| 10 3 | —1 3 | 10 | —0 5 | 0 8 | 0 6 | + | 0 |
| — | — | 17 | — | — | 0 6 | + | 0 |
| 5 3 | —0 8 | 17 | —0 7 | 0 1 | 0 7 | | |
| 0 2—10 3 | —1 3——0 2 | | —0 8——0 5 | —0 6——0 8 | | | |

of hydergine, with a consequent redistribution of blood to peripheral areas previously undersupplied This effect in particular, and to some extent the vasodilative effect, have been suggested to explain the fact that oral doses of hydergine shorten the healing time in ischaemic ulcers of the lower limb (HAEGER 1965)

The effect of vasodilative substances on the arteriograms of subjects with intact blood vessels and patients with arteriosclerosis does not seem to have been investigated previously, and a comparative investigation of the effects of bradykinin and hydergine therefore seemed indicated

*Material and Methods* Twelve patients were investigated, five of whom were women aged 32 to 76, and seven were men aged 26 to 73 years. One patient

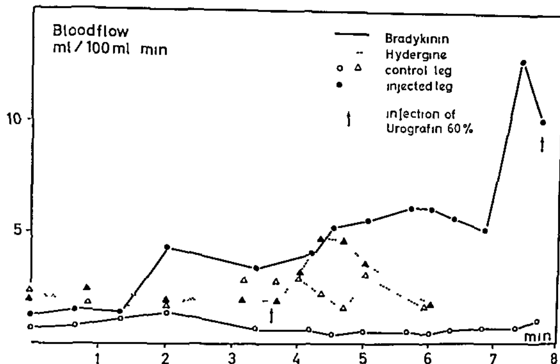



Fig 1 Case 11 Male, aged 26 with posttraumatic narrowing of the popliteal artery Bradykinin in a dose of 10 µg/min induced increased blood flow which reached a maximum after 7 minutes Hydergine, in a dose of 0 6 mg, had no effect on the flow The arrows indicate the time of contrast medium injection The short increase in flow that can be seen after injection of the contrast medium in the hydergine treated leg is typical of such an injection and within ordinary limits (Cf fig 3 )

(Case 9), aged 52, had arterial hypertonia (210/120 mm Hg) and weighed 81 kg The other patients had normal blood pressures and weights Seven patients had arteriosclerosis and four had intact arteries One patient (Case 11) had undergone operation before the investigation (see Table)

The examinations were always performed in the morning in a laboratory with a room temperature of about 23° C The patients were premedicated with 0 1 g pentymal and subjected to measurement of the resting blood flow in the supine position under the influence of test drugs and arteriography

The blood flow in both lower legs was measured by venous occlusion plethysmography according to a method described by Dohn (1956) and Graf (1964)

Catheters were introduced percutaneously for arteriography via the femoral artery In nine patients the tip of the catheter was located about 6 cm above the site of puncture, which was anaesthetized locally In three patients the catheter was inserted to a point about 5 cm above the aortic bifurcation (see Table)

Preliminary arteriography was performed without any preceding injection of test drugs The blood flow was usually measured during arteriography The

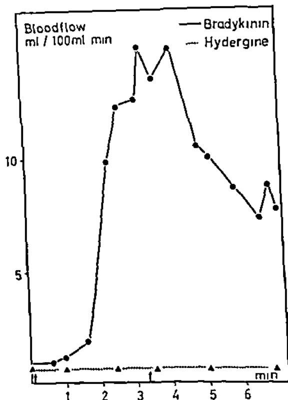



Fig 2 Case 5 Male aged 52, with bilateral arteriosclerosis The blood flow began to increase 2 to 3 minutes after the start of an injection of bradykinin in a dose of 10 $\mu$g/min After injection of 0 6 mg hydergine at 0 min and 3 3 minutes (arrow) there was no effect on the blood flow The arteriographies were performed at 7 minutes

patient then rested for 30 minutes, after which bradykinin (Sandoz AG, Basel) dissolved in physiologic saline was infused via the catheter in varying doses of up to 30 $\mu$g per minute The infusion in nine patients was given into one leg while the other leg served as control In three patients bradykinin was infused into the aorta, and thus affected both legs

When the patient had a sensation of warmth and flushing of the skin, which sometimes did not occur until about 10 minutes after the start of the infusion, further arteriography was performed The injection of contrast medium, which was given through the same catheter as had been used previously for the bradykinin infusion, had to be performed as rapidly as possible because of the short decomposition time of this drug The contrast medium was injected within 10 seconds of the end of the bradykinin infusion

The patient then again rested for 30 minutes and thereafter was given a slow intraarterial injection of 0 3 to 1 2 mg hydergine Further arteriography was carried out, under otherwise identical conditions, between 3 and 5 minutes later

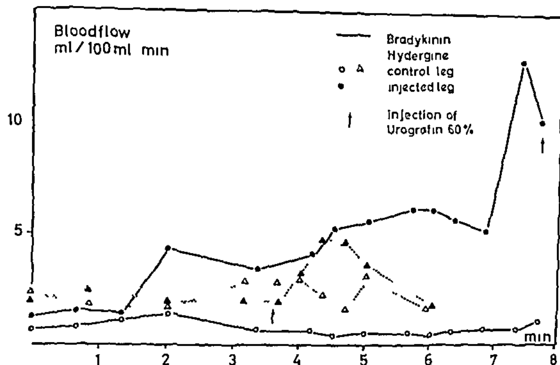



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(Case 9), aged 52, had arterial hypertonia (210/120 mm Hg) and weighed 81 kg The other patients had normal blood pressures and weights Seven patients had arteriosclerosis and four had intact arteries One patient (Case 11) had undergone operation before the investigation (see Table)

The examinations were always performed in the morning in a laboratory with a room temperature of about 23° C The patients were premedicated with 0 1 g pentymal and subjected to measurement of the resting blood flow in the supine position under the influence of test drugs and arteriography

The blood flow in both lower legs was measured by venous occlusion plethysmography according to a method described by DOHN (1956) and GRAF (1964)

Catheters were introduced percutaneously for arteriography via the femoral artery In nine patients the tip of the catheter was located about 6 cm above the site of puncture, which was anaesthetized locally In three patients the catheter was inserted to a point about 5 cm above the aortic bifurcation (see Table)

Preliminary arteriography was performed without any preceding injection of test drugs The blood flow was usually measured during arteriography The

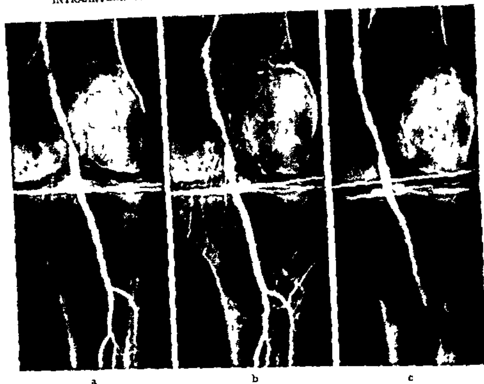



Fig 3 Case 11 Arteriography without drug (a), after injection of bradykinin (b) and after injection of hydergine (c) (Cf fig 1)

very slightly after the bradykinin injection In two other patients with intact blood vessels the blood flow was not measured In Cases 10 and 11, hydergine resulted in no definite change in the flow In all nine patients, bradykinin usually produced improvement of the peripheral contrast filling Hydergine resulted in no or decreased filling of the peripheral arteries (Fig 3)

None of the patients experienced discomfort after the injection of bradykinin or hydergine No change in the blood pressure was observed

## Discussion

The peripheral contrast filling in arteriography may be difficult, particularly with a poor blood flow Bradykinin often induces an increase in flow, thus improving the filling (Erikson 1965) Intraarterial injection of bradykinin into the femoral artery in arteriosclerotic patients also produced an increase of the flow in the calf, and the filling increased in four out of five patients

Hydergine, on the other hand, had relatively little influence on the flow and

For the arteriographies, 20 to 30 ml Isopaque 60 % or Urografin 60 % were injected with an automatic pressure syringe (5 kp/cm$^2$) The exposure frequency was 1/second The film-focus distance and other technical factors were identical for all the patients

The arteriographic findings were graded as regards changes in the superficial femoral artery and the popliteal artery (DELIUS & ERIKSON 1969), as follows

Grade 0 — No marked change in the lumen
" 1 — Marked changes at one or several sections within the artery but no more than 50 % stenosis in the lumen
" 2 — Stenosis of more than 50 % in one section but no total occlusion
" 3 — Stenosis of more than 50 % in two or more sections but no total occlusion
" 4 — Total occlusion of at least one section of the artery

## Results

The blood flow was measured continuously during the infusion of bradykinin, up to about 2 minutes after the injection of contrast medium and for about 45 minutes after the injection of hydergine

After commencement of the bradykinin infusion, the blood flow increased within 2 to 7 minutes to relatively high values (Figs 1 and 2) When the flow had reached these values the patients had a sensation of warmth in the sole of the foot After completion of the bradykinin infusion the blood flow decreased rapidly (within 20 to 40 seconds) to the resting values The contrast medium was therefore always injected within a very short period following the end of the bradykinin infusion

Infusion of hydergine had very little effect on the flow (Figs 1 and 2)

The results are presented in a Table, which includes age, sex, diagnoses and doses, as well as catheter positions, resting blood flows and maximal changes in flow after injection of the vasoactive substances

Bradykinin in the two patients with arteriosclerosis resulted in a small degree of vasodilatation when injected into the aorta In the patient with intact blood vessels (Case 3) marked vasodilatation was observed The peripheral demonstration of the arteries was improved in all the patients A slight reduction of the flow occurred in all the three patients in whom hydergine was injected into the aorta

In five patients with arteriosclerosis, the blood flow increased considerably when bradykinin was injected into the femoral artery, in these patients, hydergine had little effect on the flow In one patient with intact blood vessels (Case 11) (Figs 1 and 3), the flow increased after the bradykinin injection and decreased slightly after the hydergine injection In a woman (Case 10), the flow increased

## ZUSAMMENFASSUNG

e

graphie ist als Hydergin Hydergin versagt bei der Anwendung sowohl bei normalen als auch bei arteriosklerotischen Arterien der unteren Extremitaten.

## RÉSUMÉ

*L auteur a etudie l effet d agents* vasodilatateurs sur les arteriographies de douze sujets ayant des vaisseaux intacts ou arterio scléreux La bradykinine est préférable a l hydergine comme agent vasodilatateur administre par voie intra arterielle en arteriographie L hydergine semble dépourvue d effets vaso-dilatateurs sur les membres inferieurs arterio sclereux *ou non arterio sclereux.*

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caused no improvement but rather a deterioration of the peripheral contrast filling, both in patients with intact vessels and in patients with arteriosclerosis This is surprising, since hydergine has long been used for peripheral vascular disease and is given orally, subcutaneously or intramuscularly It has also been recommended for intraarterial use in acute peripheral arterial insufficiency, even though no objective methods of measurement have been employed in the assessment of its acute effects The therapeutic action attributed to hydergine need not with certainty be associated with vasodilatation The substance can intercede favourably in the cell metabolism, as demonstrated by EMMENEGGER & MEIER RUGE (1968) in histochemical, circulatory and neurophysiologic studies in cats These authors found that hydergine improved the pathologically altered brain metabolism and excerted an effect only under conditions of impaired energy formation

Further investigations on the influence of hydergine on the cerebral blood flow have been made by GERARD et coll (1963), among others These authors reported that hydergine administered intravenously produced a significant increase in the cerebral blood flow and increased the cerebral oxygen utilization in 18 patients, fifteen of whom had vascular lesions.

The results of the present investigations, however, do not seem to motivate the use of hydergine in acute arterial insufficiency, nor as an agent for improving peripheral arteriography For these purposes it would appear well worth trying intraarterial administration of bradykinin both in the acute stage and over a longer period Owing to the short decomposition time there is no general influence but only a local effect The present author in connection with other investigations tested an infusion of bradykinin for 20 hours, no side effects were observed and the effect on the blood flow was good

GILLESPIE (1959) discussed the use of vasodilative substances for therapeutic purposes in vascular disease and was doubtful of their value His investigations comprised only peroral and intravenous administrations, however

The intraarterial administration of drugs is much less common in the treatment of peripheral arterial disease It is considered to be a complicated procedure and accompanied by risks of complications Such administration of vasodilative drugs may, however, well be indicated in the roentgenologic examination of peripheral vessels in which the method includes the insertion of catheters

## SUMMARY

The effects of vasodilative agents on the arteriograms of twelve patients with intact blood [illegible] arteriosclerosis was investigated Bradykinin was found to be preferable to

legs

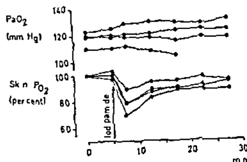



Fig 1 Effect of an intravenous injection of Iodipamide on the oxygen tension in tissue and arterial blood (recorded simultaneously)

70 000) 6 % in isotonic saline Oxygen tension ($pO_2$) in tissue was recorded by polarography with a bare-tipped platinum electrode inserted intracutaneously (GROTH) The method permits continuous registration of changes in oxygen tension but not the measurement of absolute values The oxygen tension of arterial blood was recorded with a conventional electrode The concentration of dextran in plasma was determined according to HINT & THORSEN

Four cats were given an intravenous injection of 0 5 ml per kg body weight Iodipamide in 2 to 3 seconds and recordings were made of the oxygen tension in the skin and arterial blood

Twenty four cats, divided into three groups with 8 cats in each, received two such injections at 1 hour intervals, continuous recordings being made of the skin oxygen tension and blood pressure Group 1 received no treatment between the injections, group 2 had an intravenous infusion of 20 ml Dextran 70 per kg body weight in the interval between the injections and group 3 had the same treatment as group 2 but with Dextran 40 instead of Dextran 70

## Results

*Changes in skin oxygen tension and in arterial blood* The injection of Iodipamide induced a definite drop in the skin oxygen tension in all four animals, whereas the oxygen tension in the arterial blood remained unchanged (Fig 1)

*Changes in blood pressure and skin oxygen tension before and after treatment* The first injection of Iodipamide elicited a fall in blood pressure (mean 35 %) and in the skin oxygen tension (mean 19 %) in every case

*Group 1* The fall in blood pressure in these control animals was significantly smaller after the second injection of Iodipamide than after the first injection The drop in tissue oxygen tension was also smaller after the second injection but not significantly so (see Table)

FROM THE DEPARTMENTS OF SURGERY (DIRECTOR PROF C FRANKSSON), ANAESTHESIOLOGY (DIRECTOR DOCENT B LOFSTROM) AND RADIOLOGY (DIRECTOR PROF E LINDGREN), SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

# EFFECT OF DEXTRAN SOLUTIONS ON INTRAVENOUS IODIPAMIDE TOXICITY

by

C-G GROTH, B LOFSTROM and G-F SALTZMAN

Evidence has been adduced that low molecular weight dextran reduces the adverse circulatory effects of intravenously injected radiographic contrast media This protective effect has been ascribed to the counteraction of erythrocyte aggregation or the induction of hypervolemia

The effect of low molecular weight dextran on Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was investigated in the cat Regular dextran, which induces plasma expansion without a concomitant effect on erythrocyte aggregation, was also examined

*Material and Methods* Cats weighing between 1 8 and 7 kg were anaesthetized with ether in air, tracheotomized and ventilated artificially The depth of anaesthesia and the ventilation rate were kept constant and were the same during all the experiments Iodipamide was administered as methylglucamine salt in a 50 % solution (Biligrafin forte) The dextran solutions infused were Dextran 40 (Rheomacrodex, $M_w = 40\,000$) 10 % and Dextran 70 (Macrodex, $M_w =$

This work was supported by grants from the U S National Institute of Health (H 4909) and the Swedish Medical Research Council, (B67 14x 2077) Submitted for publication 5 November 1969

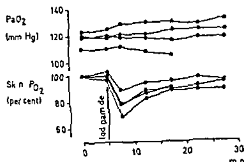



*Fig 1* Effect of an intravenous injection of Iodipamide on the oxygen tension in tissue and arterial blood (recorded simultaneously)

70 000) 6 % in isotonic saline Oxygen tension ($pO_2$) in tissue was recorded by polarography with a bare-tipped platinum electrode inserted intracutaneously (GROTH) The method permits continuous registration of changes in oxygen tension but not the measurement of absolute values The oxygen tension of arterial blood was recorded with a conventional electrode The concentration of dextran in plasma was determined according to HINT & THORSEN

Four cats were given an intravenous injection of 0 5 ml per kg body weight Iodipamide in 2 to 3 seconds and recordings were made of the oxygen tension in the skin and arterial blood

Twenty four cats, divided into three groups with 8 cats in each, received two such injections at 1 hour intervals, continuous recordings being made of the skin oxygen tension and blood pressure Group 1 received no treatment between the injections, group 2 had an intravenous infusion of 20 ml Dextran 70 per kg body weight in the interval between the injections and group 3 had the same treatment as group 2 but with Dextran 40 instead of Dextran 70

## Results

*Changes in skin oxygen tension and in arterial blood* The injection of Iodipamide induced a definite drop in the skin oxygen tension in all four animals, whereas the oxygen tension in the arterial blood remained unchanged (Fig 1)

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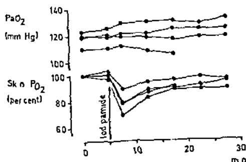



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**Table**

*Percentage drop in blood pressure and skin oxygen tension at first and second injection of Iodipamide — Mean values for the groups (n = 8)*

| | Arterial blood pressure | Oxygen tension of skin |
|---|---|---|
| Controls | | |
| First injection | 37 | 22 |
| Second injection | 27 | 17 |
| Difference ± SE | 10 ± 5* | 5 ± 4 |
| Dextran 70 | | |
| First injection | 31 | 15 |
| Second injection | 20 | 10 |
| Difference ± SE | 11 ± 5* | 5 ± 3** |
| Dextran 40 | | |
| First injection | 37 | 20 |
| Second injection | 15 | 7 |
| Difference ± SE | 22 ± 3* | 13 ± 8** |

* $p < 0.001$ ** $p < 0.01$

*Group 2* The second injection of Iodipamide, following an infusion of Dextran 70, again elicited a somewhat smaller drop in the blood pressure and skin oxygen tension than the first, the difference being significant in both (see Table). After the infusion of dextran the haematocrit reading had fallen from a mean of 42 % to 28 % and the mean concentration of dextran in plasma was 2.2 g %.

*Group 3* The second injection of Iodipamide, following an infusion of Dextran 40, elicited a considerably smaller fall in blood pressure and tissue oxygen tension than the first injection (Fig. 2), both differences being significant (see Table). After the infusion of dextran the haematocrit reading had fallen from a mean of 41 % to 26 % and the mean concentration of dextran in plasma was 2.8 g %.

Toxic manifestations were reduced for the second injection of Iodipamide to much the same extent in groups 1 and 2, whereas group 3 displayed significantly greater reductions than group 1 in blood pressure ($p \leq 0.001$) as well as in tissue oxygen tension ($p \leq 0.05$) (Fig. 3).

## Discussion

A drop in blood pressure is a familiar complication in the intravenous injection of contrast media (READ, GARBER & READ, BERNSTEIN & EVANS, SALTZMAN & SUNDSTROM, LINDGREN et coll.) and the same phenomenon has been observed when other hypertonic solutions are administered (ELIAKIM et coll.,

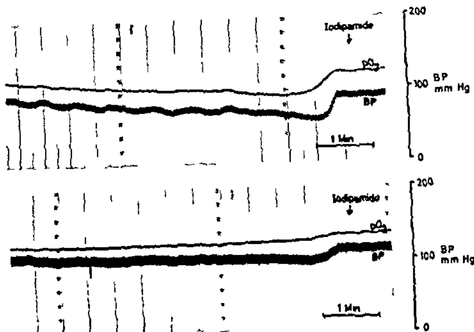



*Fig* 2 Typical changes in blood pressure and tissue oxygen tension on the intravenous injection of Iodipamide before (*upper curve*) and after (*lower curve*) an infusion of Dextran 40 (The curves should be read from right to left)

READ et coll ) This effect has been ascribed to increased pulmonary resistance, resulting in reduced cardiac output and venous stasis. It has been suggested that the increased pulmonary resistance is due in turn to the hypertonic solutions inducing a crenation and aggregation of erythrocytes (SOBIN et coll , WIEDMAN, LINDGREN et coll )

It has been found that the fall in blood pressure on the injection of Iodipamide is accompanied by a reduction in peripheral blood flow (LINDGREN & SALTZMAN) Reduced blood flow seems to be the best explanation for the present finding of a drop in tissue oxygen tension since no significant change in the oxygen tension of arterial blood occurred The fact that the changes in blood pressure were always parallelled by changes in tissue oxygen tension indicates that the peripheral effect was chiefly a passive result of the pressure drop The intra arterial injection of contrast media leads to a reduction in the peripheral resistance (LINDGREN & TORNELL, LINDGREN et coll ) and an increase in the tissue oxygen tension (HOL), probably by eliciting vasodilation, this mechanism

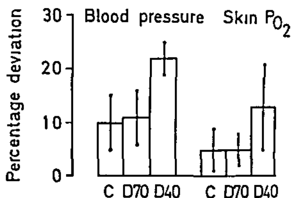



Fig 3 Difference in effect of the first and second injection of Iodipamide in the various groups Mean values and standard errors

does not however appear to have any appreciable influence on conditions after the *intravenous administration*

Previous studies on the circulatory effects of Iodipamide injections have indicated that repeat injections have a tachyphylactic effect (LINDGREN & SALTZMAN) This phenomenon was also observed in the present investigation but, with an interval of one hour between the injections, the difference in effect was not large

Several authors have found that low molecular weight dextran affords protection from the adverse circulatory effects of the intravenous administration of hypertonic contrast media (BERNSTEIN et coll, SESSIONS et coll, LINDGREN et coll) This protection has usually been attributed to favourable rheologic properties of the dextran Results obtained by GARBER et coll and WIEDMAN suggested, however, that the protection more probably derived from an induced hypervolemia

In the present experiments, juding from the changes in haematocrit readings, the two dextran solutions elicited equally large expansions of the plasma volume but only the low molecular fraction modified the circulatory effects of Iodipamide The results therefore support the opinion that protection from the toxic effects of intravenous contrast media afforded by low molecular dextran is conveyed by a mechanism other than an increase in plasma volume. This mechanism, which has not been investigated further, could involve a counteraction by the dextran of haemorrheologic disturbances elicited by the contrast medium

## SUMMARY

The effect of low molecular weight and ordinary dextran on intravenous Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was examined in the cat Both dextran solutions induced hypervolemia but only the low molecular weight fraction had a significant protective action It seems likely that this beneficial effect was mediated through a rheologic mechanism

## ZUSAMMENFASSUNG

Die Wirkung von Dextran mit niedrigem Molekulargewicht und von normalem Dextran auf die Toxicitat von intravenos zugefuhrtem Iodipamide wie sie im arteriellen Blutdruck und dem Gewebs Sauerstoffdruck zum Ausdruck kommt, wurde bei der Katze gepruft Beide Dextran Losungen verursachten eine Hypervolamie, aber nur die Losung mit niedrigem Molekulargewicht hatte einen signifikanten Schutzeffekt. Es erscheint Wahrscheinlich, das der gunstige Effekt uber einen regulatorischen Mechanismus der Cirkulationsverhaltnisse erfolgt

## RÉSUMÉ

Les auteurs ont étudie sur le chat l effet du dextran de faible poids moleculaire et du dextran ordinaire sur la pression arterielle et la tension en oxygene des tissus prises comme temoins de la toxicite de l Iodipamide administre par voie intra veineuse Ces deux solutions de dextran causent une hypervolemie, mais seule la fraction de faible poids moleculaire a un effet protecteur important. Il parait vraisemblable que cet effet favorable est du à un mecanisme rheologique

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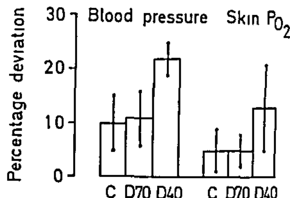
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# EXPERIMENTAL LYMPHOGRAPHY IN CARDIAC ARREST, ELECTRICAL VENTRICULAR FIBRILLATION AND DEEP HYPOTHERMIA

by

A CELIS, M A MENA and H DEL CASTILLO

The normal lymphographic and lymphatic flow patterns have been studied in canine hearts under normal conditions Experimental myocardial infarction as well as trials in human subjects have proved the procedure to be innocuous (CELIS et coll 1966, 1967, 1968, 1969)

*It is sometimes necessary in modern cardiac surgery to decrease* or *interrupt* cardiac flow by modifying or temporarily abolishing cardiac contraction this can be obtained by complete cardiac arrest, electrical ventricular fibrillation or bradycardia with hypothermia Spontaneous cardiac arrest is clinically a fairly frequent occurrence, and occasionally effective cardiac contraction is resumed With the advent of cardiac transplantation of hearts with spontaneous arrest, which due to technical problems are subject to variable episodes of total ischemia, the need for careful evaluation of myocardial alterations during and after these natural or technically induced conditions is most urgent (BOLOOKI et coll 1968, CONN et coll 1959, HUFNAGEL et coll 1961, LAWRENCE et coll 1965, POULIAS et coll 1965, STONEY et coll 1964, WALDHAUSEN et coll 1960, WILLIAMS et coll 1959)

As regards the lymphatic system, only increased thoracic duct flow has been demonstrated during extracorporeal circulation (BALE et coll 1965) The state

Submitted for publication 5 December 1969

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Fig 4 a) Lymphatic morphology and normal flow pattern adequate myocardial contraction in the perfused heart the myocardial and mediastinal collectors are visible b) Normal myocardial lymphatic system industrial film was used

of the myocardial lymphatics during and after arrest or ventricular fibrillation is unknown This lack of knowledge in cardiac pathophysiology suggested our investigation of the possibilities of absorption and drainage of contrast media in the myocardial interstitial space during and after cardiac arrest, electrical ventricular fibrillation and bradycardia, in an attempt to correlate coronary perfusion and lymphatic flow rate in a heart resected for transplantation

*Material and Method* The experiments were performed with the Heyman technique (Figs 1 2 and 3) Cardiac arrest was obtained by means of potassium citrate solution 0 25 % with cross clamping of the aorta or with intermittent episodes of ischemia (three times one minute) Ventricular fibrillation was produced by electric shock and deep hypothermia (Fig 2) By an arrangement similar to the one described by Lagendorf, the changes in lymphatic circulation

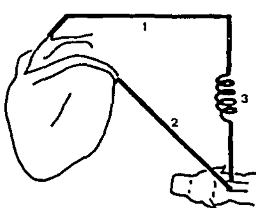



Fig 1 Innominate artery (1) and pulmonary artery (2) of the recipient dog joined to the carotid artery and jugular vein of the donor dog The blood to the isolated heart passes through a coil (3) maintained at a constant 40° C in water

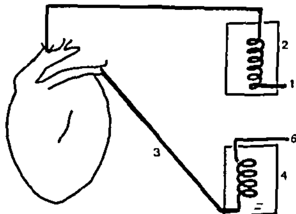



Fig 2 The blood to the perfused heart (1) cooled (15 to 18° C) by being passed through a coil immersed in water (2), the blood returning to the donor dog (3) being reheated while passing through a coil (4) submerged in hot water, maintained at 40° C

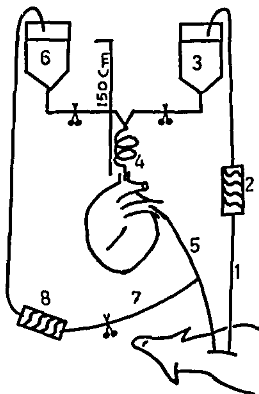
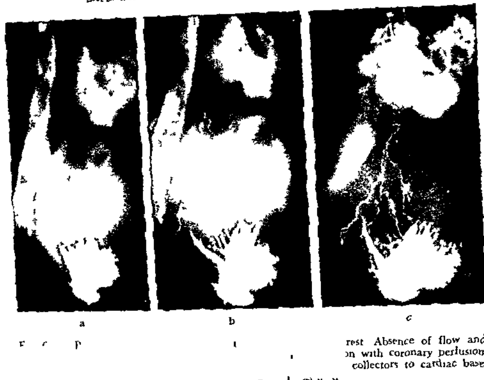



Fig 3 The perfusing dog blood (1) is raised by a Sigmamotor pump (2) to a reservoir (3) 135 cm above the perfused heart The blood maintained at a temperature of 38° C (4) passes to the innominate artery of the resected heart venous blood from the pulmonary artery going to the jugular vein of the donor animal (5) Blood with potassium citrate solution 0 25 % contained in a second reservoir coupled to the system (6) produces complete arrest Potassium blood may thus be changed for normal blood as required A bypass (7) and Sigmamotor pump (8) returns the potassium blood to the reservoir (6) and prevents its passage to the donor dog




rest Absence of flow and
on with coronary perfusion
collectors to cardiac base

## Results

The absorption of contrast medium in the interstitial space with lymph drainage and flow identical to the normal pattern reported previously is shown for the control cases in Fig 4

In condition (2), the contrast medium was observed in the interstitial space, i e the coronary veins and sinus were rendered visible, in other words, a coronary phlebogram was obtained, due apparently to blockage of the contrast medium at the terminal lymphatics (Fig 5, a and b) Under the conditions indicated in (2b) as perfusion with normal blood is resumed, the contrast medium rapidly disappears from the venous system and appears in the lymphatics with normal morphologic and dynamic characteristics (Fig 5c) The drainage of the interstitial space by the lymphatics is resumed with myocardial contraction

In cardiac arrest or ventricular fibrillation due to intermittent ischemia, i e conditions in (3), poor absorption or drainage of the contrast medium occurred (Fig 6a) but it was overcome with re instatement of the coronary circulation and effective myocardial contraction (Fig 6, b and c)




Fig 5 a) Complete coronary phlebogram by absorption and drainage through venous capillaries No absorption by lymphatics in heart with total ischemia due to potassium induced arrest b) Venous drainage of contrast medium to the coronary sinus Total ischemia due to potassium induced arrest c) Normal lymphatic drainage and flow in heart recuperated by coronary perfusion, same case as in (b), industrial film was used

during potassium induced arrest with maintained coronary perfusion were studied (Fig 3)

Lymphography, in the manner described in a former work (CELIS et coll 1966), was carried out with serial radiography in twenty-nine resected hearts using conventional and industrial film The method employed permitted a study of the cardiac lymphatic system under the following experimental conditions

1 Lymphography in resected and perfused active hearts 4 experiments

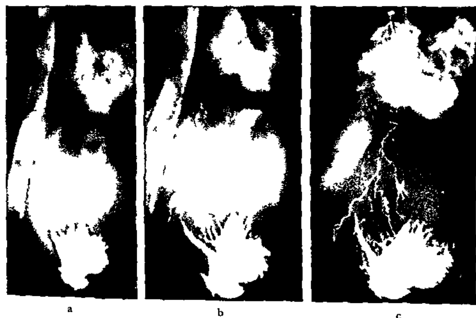
2 Lymphographic changes during potassium-induced arrest without coronary perfusion (a), and after coronary flushing with normal blood (b) 8 experiments

3 Lymphographic patterns during cardiac arrest or ventricular fibrillation induced by intermittent ischemia, and during resumption of perfusion and effective myocardial contraction 2 experiments

4 Lymphographic changes during electrically induced ventricular fibrillation with coronary perfusion and during recovery to sinus rhythm 7 experiments

5 Lymphography during severe bradycardia (8 per minute) with deep hypothermia (15 to 18° C), maintaining coronary perfusion with an extracardiac system and return to sinus rhythm and normothermia 3 experiments

6 Lymphography during potassium induced arrest, maintaining coronary perfusion with an extracardiac system (Langendorff preparation) 5 experiments



a b c

Fig 6 p [illegible] rest Absence of flow and [illegible] n with coronary perfusion [illegible] collectors to cardiac base

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Fig 7 a) *Interstitial* space and lymphatic flow through myocardial collectors to base of heart in electrical ventricular fibrillation and coronary perfusion b) Same case as in (a) Interstitial space lymph flow through lateral collectors cardiac nodes and mediastinal collectors demonstrated by the use of *industrial film* c) Roentgenogram obtained 8 minutes after injection of contrast medium and lymph flow in heart perfused with 18° blood Marked bradycardia. Compare this with fig 8a

In electrical ventricular fibrillation with maintained coronary perfusion, conditions in (4), the morphology and flow of the lymphatic system were normal (Fig 7, a and b)

In bradycardia with hypothermia and with maintained coronary perfusion by an extracardiac system, conditions in (5), the morphology of the lymphatics *was in accord with normal appearances (Figs 7c and 8a) The flow is slow* and becomes re activated with warming of the blood to normal temperature and a return to normal cardiac rate

In cardiac arrest with potassium and with maintained extracardiac perfusion, conditions in (6), the absorption, drainage and flow of the contrast medium were normal (Fig 8b)

## Discussion

The relationship between coronary perfusion or myocardial ischemia and the absorption and drainage of contrast media injected into the connective tissue were carefully considered in the investigation The anatomical and functional




Fig 8 a) Same case as in fig 7c Interstitial space and lymph flow to mediastinal collectors, industrial film was used b) Langendorff arrangement potassium induced cardiac arrest coronary perfusion with extracorporeal circulation Absorption of contrast medium by the lymphatic system

state of the lymphatic system of the resected heart that had recuperated with coronary perfusion, after repeated episodes of ischemia, was also studied

It was assumed that absorption and drainage of a contrast medium by the cardiac lymphatics primarily depends on adequate coronary perfusion and secondarily on myocardial contraction This hypothesis was supported by the following facts

With adequate coronary perfusion during potassium induced arrest, electrical ventricular fibrillation and bradycardia due to hypothermia, the absorption of the contrast medium from the interstitial space and its flow through the lymphatics could be demonstrated

Without coronary perfusion, the lymphatic terminals are apparently selectively blocked for the contrast medium, which drains through the venous system With coronary perfusion re-established, the normal physiologic conditions of the connective tissue return, the venous capillaries are closed to the medium, and lymphatic absorption and drainage take place

The passing of fluid and particles through the lymphatic endothelium may occur through the intercellular fissures or the vesicles of the limiting membrane The intercellular junctions, when open, form regular channels from the surrounding intercellular spaces of the connective tissue to the lumina of the lymphatic terminals (LEAK et coll 1968) We have found that in normal (adequate coronary perfusion and myocardial contraction) conditions, the aqueous contrast media (low molecular weight) instilled in the myocardial connective tissue, drain rapidly and selectively by the venous system and the large particles of e g Lipiodol Ultrafluide drain slowly through the lymphatic system Large particles of contrast medium drain selectively through the lymphatic terminals as these have a 3 to 5 times greater diameter than the vascular capillaries (CASTLEY—SMITH 1965, 1967, PATEK 1939) and the intercellular junction, when open, is larger (LEAK et coll ) The following conditions are obtained when many of these junctions are open flow in the collecting lymphatics with low terminal pressure, muscular contraction, variations in tissue pressure, with metabolic activity and accumulation of high molecular weight metabolites, which increases capillary filtration and produces a current that carries the large particles and opens the intercellular junctions

It is recognized that if the lymphatic terminals permeate the Lipiodol Ultrafluide particles this must be due to the fact that many junctions are open, and that any blockage must be due to their being closed If absorption and drainage coincide with adequate coronary perfusion, and blockage with myocardial ischemia, respectively, it must be accepted that in the first situation the junction is open and in the second instance closed

On the basis of the previous considerations we feel that in the perfused heart, with or without myocardial contraction, the contrast medium deposited in the interstitial space becomes incorporated in the interstitial fluid formed by capillary filtration and myocardial metabolism The fluid current would thus be established by a pressure gradient that carries the large particles (Lipiodol droplets) to the lymphatic lumina, circulating through them as lymph The lymphographic flow patterns of this current, from the coronary capillaries to the mediastinal lymphatics and their venous junction, signify the existence of blood perfusion and probably myocardial metabolism

Blockage of the terminal lymphatics to Lipiodol particles occurs in the nonperfused heart which drains selectively through the venous system This blockage

may possibly be explained by the absence of capillary filtration, and a pressure gradient and fluid current which fail to open the intercellular junctions. The drainage through the venous system caused by various factors is inherent in [illegible] the absence of intracapillary hydrostatic pressure,

In cardiac transplantation, the resected and isolated donor heart has [illegible] lymphatics severed It has been *subjected for periods of* 5 minutes to spontaneous arrest and total ischemia, and, during the time required to establish extracorporeal circulation, to repeated *episodes of ischemia* The ill effects of these adverse conditions to the recuperation and viability of the transplanted organ may be attenuated *by hypothermia at 26° C*, perfusing the isolated heart at a rate of 300 to 400 ml per minute, implanting it in the recipient at a temperature of 30 to 32° C *and anastomosing the aorta last, in order to decrease the time of ischemia* (Barnard 1967, 1968) The hearts transplanted by Cooley et coll (1968) *are provided by individuals within hours of cerebral death and are resected before* spontaneous arrest, they are subjected to short, repeated episodes of ischemia that *total about* 45 *minutes with normothermia* and *without artificial perfusion* Transplanting a heart under these conditions poses problems for the recovery *of effective and sustained myocardial contraction, these include the viability* (Debakey 1968), rejection and mutual organ host tolerance of the transplanted heart

One of the numerous difficulties presented by this procedure is the cardiac lymphatic *morphology and flow* We feel that, *as in these experimental cases* with a perfused heart, the absorption, drainage and flow of the contrast medium in the donor heart is maintained during the handling *and first hours of transplant* as long as there is adequate coronary perfusion This extrapolation would appear to be acceptable because both hearts have been *resected, isolated,* perfused and revitalized by coronary perfusion after transient and repeated episodes of hypothermia and ischemia

The fate of the lymphatic system in transplanted organs is interesting and according to the literature (Cooley et coll 1968, Chavez 1967) has been studied in pulmonary re implantation and heterotopic renal autotransplantation into the pelvis It is stated that during the first two or three weeks *the lymphatic* flow is replaced by lymphectasia and probable lympho-venous communications Lymphography in the resected and perfused hearts of the present *series* demonstrated absorption in the interstitial space and flow of the contrast medium to the severed mediastinal collectors during the first few hours

## SUMMARY

The morphologic, dynamic and lymph flow changes during cardiac arrest and ventricular fibrillation in the usual surgical procedures and heart transplantation in 29 resected hearts are described. Positive cardiac lymphography appears to indicate satisfactory coronary perfusion, capillary filtration and probably maintained myocardial metabolism.

## ZUSAMMENFASSUNG

Die morphologischen, dynamischen und lymphologischen Flussveränderungen während Herzstillstand und Herzflimmern bei der gewöhnlichen Operation und der Herztransplantation in 29 Herzen werden beschrieben. Die positive Lymphographie des Herzens scheint gute Durchströmung und gute kapillare Filtrierung und wahrscheinlich einen befriedigenden Stoffwechsel des Myokards anzuzeigen.

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Description des modifications morphologiques, dynamiques et des débits lymphatiques pendant l'arrêt cardiaque et la fibrillation ventriculaire au cours des interventions chirurgicales habituelles et au cours de la transplantation cardiaque sur 29 cœurs prelevés. Une lymphographie cardiaque positive paraît indiquer une perfusion coronaire satisfaisante, une filtration capillaire et probablement le maintien du métabolisme myocardique.


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Fig 1 Arterial phase in normal angiography of a renal allograft 24 hours following transplantation

changes of rejection The primary renal disease had been chronic glomerulonephritis in fourteen patients, chronic pyelonephritis in two and polycystic kidneys in two patients All but one graft were obtained from non living donors The transplants were anastomosed to the iliac vessels, generally the renal artery end to end with the internal iliac artery and the vein end to-side with the common iliac vein Immunosuppressive therapy consisted of prednisone or its analogues and azathioprine, actinomycin C was used in a few patients Earlier patients were also treated with graft irradiation

*Examination methods* The percutaneous technique with a Kifa red or thin-walled red catheter was used Generally the contralateral femoral artery was punctured and the tip of the catheter placed in the ipsilateral common iliac artery as near as possible to the origin of the internal iliac artery Selective injection of

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON) THE UNIVERSITY HOSPITAL, LUND, SWEDEN, AND THE DEPARTMENTS OF RADIOLOGY (DIRECTOR PROF CLYDE M WILLIAMS), SURGERY (DIRECTOR PROF EDWARD R WOODWARD) AND PATHOLOGY (DIRECTOR PROF RICHARD T SMITH), UNIVERSITY OF FLORIDA COLLEGE OF MEDICINE, GAINESVILLE, FLORIDA, USA

# ANGIOGRAPHIC DIAGNOSIS OF REJECTION AND TUBULAR NECROSIS IN HUMAN KIDNEY ALLOGRAFTS

by

J KAUDE, D H SLUSHER, W W PFAFF and R L HACKETT

Oliguria or anuria is not an infrequent complication of renal transplantation of cadaveric kidneys (CALNE et coll 1963), the most common causes being immunologic rejection or ischemic tubular necrosis Differentiation between these disparate states may be difficult on clinical grounds alone but can usually be accomplished by percutaneous biopsy (KINCAID SMITH 1967) Not infrequently, however, the biopsy material may be insufficient to allow definite conclusions or may result in residual vascular abnormalities (SWEET et coll 1969, EKELUND 1970) and untoward effects in a critically ill patient When these limitations became apparent angiography was employed to aid in the diagnosis of these and other causes of functional failure of a renal graft

*Material* Twenty nine angiographic examinations (19 in Gainesville and 10 in Lund) were performed in eighteen patients first and second grafts were examined in four patients The principal indication for angiography was oliguria or anuria One patient was investigated to evaluate the etiology of persistent hypertension, and two examinations were made to determine the resolution of earlier

Submitted for publication 16 December 1969




Fig 4 Cortical necrosis secondary to necrotizing vasculitis examination performed 24 days following transplantation a) Kidney not enlarged marked truncation of the interlobar arteries secondary to peripheral obstruction b) Circulation time markedly prolonged the contrast medium remaining in the kidney at 12 seconds following injection indicates presence of renal vein thrombosis

needle biopsies The latter were generally obtained within 4 days of the radiographic procedure The kidney was removed the day following angiography in one patient and open biopsy was performed in three patients Major vessel thrombosis complicating completed rejection was confirmed by graft nephrectomy Biopsies were not performed in three pat ents [illegible] angio- patient [illegible] ndings.

## Results and Discussion

Only one angiographic examination was normal (Fig 1) Acute rejection was demonstrated in ten examinations and chronic or healed rejection was noted in four Rejection vasculitis had caused obstruction of the interlobar arteries



Fig 2 Acute rejection 51 days following transplantation Kidney edematous, arteries stretched and peripheral vessels unfilled, irregularities in the arterial lumen are localized in the pars intermedia The arterial emptying time was 6 seconds Light microscopy showed severe rejection, with necrotizing vasculitis



Fig 3 Acute rejection with severe vasculitis but without marked renal edema examination performed 7 days following transplantation and 2 days after marked decline in function The arterial emptying time was 3 seconds Renal veins not demonstrated, faint nephrographic phase

the internal iliac artery was performed in three instances, 10 to 15 ml of Renografin 60 % or Isopaque Cerebral were injected by hand In common iliac injections, 12 to 30 ml were used, the volume varying with the size of the artery and the age of the patient

The films were exposed in an Elema-Schonander 14" × 14" cut film changer, the film rate being 2 per second for 3 seconds, 1 per second for 3 seconds, and an additional 3 films in 6 or 9 seconds A late exposure was obtained to determine the presence or absence of excretion of contrast medium by the graft In one patient, retrograde pyelography was performed immediately following angiography, and in some instances 70-mm serial fluorography at a rate of 3 films per second was performed for a more accurate estimation of the renal circulation time The focal spot was 0 6 or 1 2 mm No complications from the procedure were observed

Angiographic findings were compared with histologic diagnoses of percutaneous



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thrombosis ultimately leading to obliteration Medial ne o h

... 1963 1965, 1967, KINCAID SMITH 1967) *Tubular atrophy* segmental infarction, cortical necrosis or ultimately completed organ infarction may develop as a consequence of vascular obliteration

As the primary site of rejection is the vessels, angiography is a particularly apt diagnostic method of demonstrating the reaction In earlier investigations angiographic findings in rejection of human renal transplants have included edema, prolongation of the arterial circulation time, irregularities and oblitera

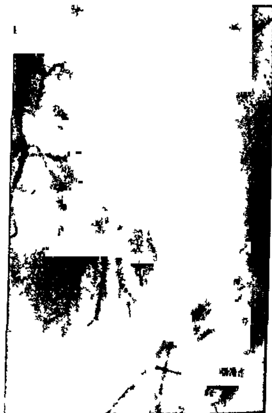


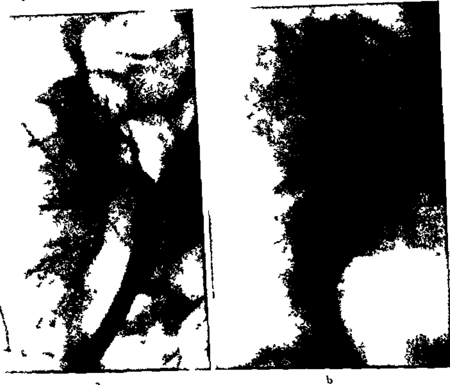
Fig 5 Chronic or healed rejection angiogram 10 months following transplantation Kidney of normal size narrowing of interlobar arteries and reduced number of peripheral cortical arteries as well as medullary branches The arterial emptying time was 2 7 seconds Kidney functioning although at half the maximal initial function

resulting in uniform cortical necrosis associated with renal vein thrombosis in two examinations In one examination, cortical necrosis resulted from ischemia due to renal artery obstruction of several hours duration Signs of both acute and chronic rejection were noted *in one patient*

Anuria in four patients appeared to be the consequence of ischemic acute tubular necrosis, although it was eventually associated with focal rejection Thrombosis of the arterial anastomosis was revealed in two examinations The anastomosis was stenotic in two grafts and in one patient narrowing with poststenotic dilatation was noted at the origin of the internal iliac artery A blood clot obstructed the ureteropelvic junction in one patient, this was confirmed by pyelography

There was uniform correlation of the angiographic diagnosis with either histologic data or clinical conclusions as evidenced by the end results

Convincing evidence has been presented that the primary site of immunologic *rejection of renal transplants is the vascular endothelium* (KOUNTZ et coll 1963, KNUDSEN et coll 1967) Rejection vasculitis has been characterized by subintimal round cell infiltration and fibrin deposits resulting in mural



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e e s in contrast st nct on to the non f ll ng character st c of m munologic rejection

are stretched by edema irregularities in the arterial lumen caused by subintimal and mural cellular infiltration are present If angiography is repeated following intensification of immunosuppressive therapy, the edema of the kidney may be less marked although vascular changes may persist (Fig 3)

The arterial circulation time is prolonged and varies with the severity of the rejection In clear cut rejection the arterial phase varied from 2 5 to 6 seconds In three patients with mild rejection the arterial phase was normal (1 to 2 seconds) This was determined by the interval between the appearance of the last portion of the contrast medium in the renal artery and the emptying of the peripheral arteries This method of estimating the arterial emptying time is obviously not very accurate but with the angiographic technique employed (injection of contrast medium into the common iliac artery and a film rate



Fig 7 Angiography in acute tubular necrosis in kidney (not transplanted) examined 7 days following onset of anuria a) Normal kidney size arteries unremarkable with emptying time of 1 5 seconds b) Good nephrographic phase and filling of veins no contrast medium in the collecting system in the late films

tion of the arteries, with absence of the peripheral vasculature and a poor nephrographic phase (ALFIDI et coll 1966, O CONNOR et coll 1967, STAPLE & CHIANG 1967, BRUCKE et coll 1968, KAUDE et coll 1969, VINIK et coll 1969) In experiments with canine renal transplants, the angiographic findings in rejection have been found to be essentially similar to those in clinical work in man (DEMPSTER 1955, KNUDSEN et coll 1967)

Angiographic findings in tubular necrosis caused by prolonged renal ischemia before or during grafting have been reported in only one patient and were histologically unverified (BRUCKE et coll 1968)

The angiographic findings in rejection in our material are in agreement with those reported by ALFIDI et coll, O CONNOR et coll, STAPLE & CHIANG and BRUCKE et coll We also agree with VINIK et coll in their statement that it is possible to differentiate angiographically between acute and chronic stages of rejection In acute rejection (Fig 2), the kidney is enlarged and the arteries

veins may sometimes be present in such cases and, depending on the current state of the renal function, contrast medium may be excreted

The circulation time in ischemic acute tubular necrosis (Fig 6) was normal or only slightly prolonged and, with one reservation, varied from 1 to 2 seconds In one examination, the arterial emptying time was 3 seconds, this was attributed [illegible] presence of admixed immunologic rejection In three patients [illegible]

[illegible]

biopsy (Fig 6a) No other arterial changes were noted, the [illegible] small peripheral vessels were filled with contrast medium A nephrographic effect was invariably present, although the borderline between the cortex and medulla could be hard to define The renal veins were filled in late films. Presumably, as a result of the absence of kidney function, an increased concentration of the contrast medium in the veins was usually observed (Fig 6b)

[illegible] necrosis in [illegible] patient with a non transplanted kidney (Fig 7) in whom clinical and histologic verification was consistent with the diagnosis of ischemic acute tubular necrosis. The arteries and arterial emptying time were normal, the renal veins were filled with contrast medium and nephrographic effect was present although no contrast medium was excreted

A similar identification of the renal veins was noted in a patient with cortical necrosis following renal artery obstruction of several hours duration Peripheral arterial lesions were also observed in this case (Fig 8) The latter findings were similar to those described in experimental investigations and believed to be caused mainly by renal arterial spasm (SHERWOOD et coll 1969)

Further complications following kidney transplantation, to be differentiated from acute rejection and ischemic tubular necrosis, are *renal vein thrombosis* and renal failure secondary to urinary obstruction In renal vein thrombosis, the blood flow in the kidney is retarded (CRUMMY & HIPONA 1965, KOEHLER et coll 1966 ALFIDI et coll 1966) but if not associated with or not secondary to rejection no vasculitis is present The diagnosis of renal vein thrombosis may be verified by renal phlebography (ALFIDI et coll ) In a patient with urinary obstruction (Fig 9, a and b), the renal vasculature was normal but a marked nephrographic effect persisted for more than 18 seconds Pyelography performed immediately following angiography revealed a blood clot at the ureteropelvic junction as the cause of the renal stasis (Fig 9c)

Local vascular irregularities as the result of focal rejection need to be differentiated from changes that may follow needle biopsy (SWEET et coll 1969) Percutaneous needle biopsy was performed prior to angiography in five of our




Fig 9 Kidney failure secondary to urinary obstruction 5 day old transplant a) Normal arteriography No vasculitis or renal edema the arterial emptying time was 1 5 seconds b) Marked nephrographic phase persisting for more than 18 seconds c) Pyelography revealed a blood clot at the ureteropelvic junction as the cause of the renal stasis

of 2 to 3 films per second) its application is warranted from a practical point of view and permits a determination of the arterial emptying time within the acceptable range of error, approximately 0 3 to 0 5 seconds

Additional radiographic findings depended upon the intensity of rejection, the stage at which the examination was performed, the character of the immunosuppressive therapy and the response to this treatment In acute rejection, either no filling with contrast medium of the interlobar peripheral branches and the arcuate and interlobular arteries took place or the filling was incomplete (Figs 2 and 3) The nephrographic phase was poor or absent Reduced capillary flow prevented demonstration of the veins Little or none of the contrast medium was excreted by the kidneys

With progressive rejection, the peripheral branches of the interlobar arteries, including branches descending into the medulla (KNUDSEN et coll 1967), as well as the primary interlobar vessels themselves, became obliterated, with resultant cortical necrosis (Fig 4)

Response to immunosuppressive therapy may result in conversion of the angiographic findings of acute rejection to those of healed or chronic rejection, as illustrated in Fig 5 The kidney size in this instance was decreased and the caliber of the renal arteries was reduced, although the lumina remained irregular When correlated with the microscopic findings, this appeared partly to be due to organized subintimal infiltration and interstitial fibrosis The number of interlobar arteries was reduced, presumably because of obliteration of vessels as a result of the acute rejection The circulation time was normal or slightly prolonged and ranged from 1 5 to 2 5 seconds Faint contrast filling of the

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Further verification of the angiographic findings of acute tubular necrosis in transplanted kidneys was provided by an opportunity to examine a patient with *a non transplanted kidney (Fig 7) in whom clinical* and histologic verification was consistent with the diagnosis of ischemic acute tubular necrosis. The arteries and arterial emptying time were normal, the renal veins were filled with contrast medium and nephrographic effect was present although no contrast medium was excreted

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[illegible] jection need to be dif- [illegible] (SWEET et coll 1969) [illegible] giography in five of our

patients In two of these, residual vascular irregularities but no resultant arteriovenous fistulas were observed (Fig 6a)

A summary of the angiographic findings in acute rejection and tubular necrosis is given in the following

| | *Acute rejection* | *Tubular necrosis* |
|---|---|---|
| Kidney size | Enlarged | Normal or slightly enlarged |
| Edema | Present | Absent or mild |
| Circulation time | Prolonged (normal in mild rejection) | Normal or slightly prolonged |
| Vasculitis | Present | Absent |
| Nephrogram | Poor or absent | Present |
| Renal veins | Not filled | Filled |
| Contrast excretion | Absent | Absent |

A particularly careful technique is essential in the investigation of renal transplants in order to be able to evaluate changes in small vessels Only with injection into the internal or ipsilateral common iliac arteries have we been able to obtain films of good diagnostic quality For selective techniques the introduction of a catheter into the internal iliac artery is usually preferred The anastomosis generally lies 3 to 5 cm distally from the origin of the vessel and although sub intimal injection is a potential complication it should rarely occur However antegrade semi selective injection into the common iliac artery following puncture of the contralateral femoral artery is equally successful and necessitates only a small increase in the amount of contrast medium employed It has the additional advantage of allowing more adequate evaluation of the proximal internal iliac artery A high incidence of atherosclerotic lesions occur in uremic patients even in young individuals Significant calcification of the internal iliac artery was noted on two occasions in our series and in one patient there was marked stenosis at the origin of the internal iliac artery with significant post stenotic dilatation

Further technical refinement may be achieved with a 0 3 mm focal spot and geometric magnification (TAKARO 1967 BAUM et coll 1968) This has been particularly useful in evaluating the peripheral vasculature of the kidney (TAKARO 1967 SHERWOOD et coll 1969 LAVENDER et coll 1969 OLIN & SAKUMA 1969) and may prove to be an important aid in the detection of small vessel vasculitis Clarification of peripheral lesions may also be aided by sub traction techniques

## SUMMARY

Angiography was performed on 29 occasions following 22 renal allografts in 18 human subjects and proved to be an aid in the differential diagnosis between immunologic rejection and ischemic acute tubular necrosis. The angiographic findings in the various stages of rejection in the presence of tubular necrosis and in other complications following transplantation are described These were found to correlate with the microscopic and clinical diagnoses The technique of angiography in renal transplants is discussed

## ZUSAMMENFASSUNG

Nierenangiographie wurde in 29 Fallen n
vorgenommen und erwies sich als eine we
diagnostisch zwischen Abstossungsreaktion u
*zu unterscheiden* Die angiographischen Befunde wahrend den verschiedenen Stadien der Abstossungsreaktion beim Vorliegen einer tubularen Nekrose und bei anderen Komplikationen nach Nierentransplantation werden beschrieben Die angiographischen Befunde stimmten in samtlichen Fallen mit der histologischen Diagnose und dem klinischen Verlauf uberein. Die Technik der Angiographie der transplantierten Niere wird besprochen

## RÉSUMÉ

Les auteurs ont pratique 29 angiographies apres 22 allotransplantations renales chez 18 malades cet examen s est montre utile pour le diagnostic differentiel entre le rejet im*munologique* et la necrose tubulaire ischémique aigue Les auteurs decrivent les signes angio*graphiques* aux differents stades du rejet dans le cas de necrose tubulaire et dans les autres complications *qui suivent* la transplantation Les signes angiographiques sont en concordance avec les diagnostics microscopiques et cliniques Les auteurs etudient la technique de l *angiographie* dans les transplantations renales

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR CURT JOHANSSON), CENTRALLASARETTET, BORÅS, SWEDEN

# HYSTEROGRAPHY IN INTRAUTERINE PREGNANCY AND ABORTION

## Report of three cases

by

MOGENS HONORE

Hysterography has lost much of its significance in the diagnosis of early pregnancy with the coming of biologic pregnancy tests. The procedure has, however, still been resorted to in confirming a diagnosis of tubal pregnancy or even cervical gestation (MATRACARU et coll. 1966).

HELSER (1925) was the first to inject iodinized oil into the pregnant uterus as a routine measure. MARTINEZ & MILLER (1928) reported 15 cases of pregnancy so diagnosed, three of which terminated in abortion. Hysterograms of intact intrauterine pregnancy are now obtained only accidentally. KJELLBERG (1942) observed one case in a consecutive material of 328 cases of hysterosalpingopelvigraphies and GOLDBERGER et coll. (1950) reported two cases of early pregnancy in a review of 2 500 cases. SALASC (1965) reported a case leading to a false diagnosis of uterine fibroid and put the risk of abortion following the examination at up to 10 %.

Hysterography may still be of some value in diagnosing a condition of missed

Submitted for publication 18 November 1969.




Fig 1 Case 1 Intact intrauterine pregnancy Hysterography oblique anteroposterior (a) and lateral (b) views

abortion AHUMADA et coll (1956) reported 13 cases in eleven of which a correct diagnosis was apparently made These authors stressed that hysterography should not be performed unless death of the embryo is certain, and that at least 10 to 15 ml of the aqueous contrast medium should be used to obtain a reasonable filling of the enlarged cavity

The hysterogram of early intact pregnancy generally reveals an enlarged, atonic and globular cavity with a rounded contrast defect close to the wall and a small cervical canal In certain instances, including missed abortion, the defect may be more irregular and suggest carcinoma of the corpus, submucous and intra mural fibromyoma, or endometrial polyps The changes may be difficult to interpret and may be obscured by a combination of conditions or by infection (The reader is referred to SCHINZ 'Lehrbuch der Rontgendiagnostik' 1965, DALSACE et coll 1959 and ERBSLOH 1957 )

*Material* This consisted of 1 266 hysterographies performed during the period 1964—1969 Three cases of intrauterine pregnancy and abortion were encountered and are now reported

## Case reports

*Case 1* Woman, aged 23 was admitted to the Gynecologic Department for treatment of a palpaple orange sized ovarian cyst Following left oophorectomy the patient had had more or less continuous abdominal symptoms suggesting adnexial inflammation but on examination the cyst had apparently disappeared No pregnancy test was performed



Fig 2 Case 2 Infected abortion Hysterography oblique anteroposterior (a) and lateral (b) views.

Hysterography revealed a considerably enlarged anteflected uterus with an internal diameter of about 11 cm (Fig 1) The cervical canal was small A rounded broad based smooth contrast defect approximately 8 cm in size lay at the fundus and the anterior wall The tubes were only partly filled The appearances were highly suggestive of pregnancy a diagnosis confirmed clinically and by a pregnancy test The pregnancy was terminated



Fig 3 Case 3 Missed abortion Hysterography oblique anteroposterior (a) and lateral (b) views

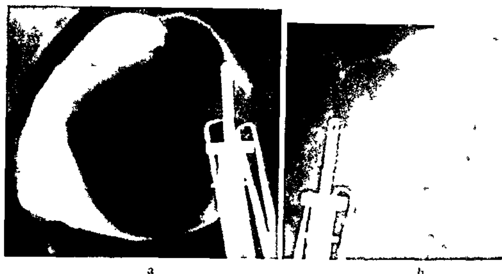



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## Case reports

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## ZUSAMMENFASSUNG

Drei Falle von Hysterographie bei intrauteriner Gravidität und Abort werden vorgelegt und die rontgenologische Diagnose wird besprochen Es wird betont, dass es wichtig ist bevor der Hysterographie eine Gravidität auszuschliessen

## RÉSUMÉ

Presentation de trois cas d hysterographie au cours de grossesses intrauterines et d avortements L auteur discute le diagnostic et souligne l importance de s assurer qu il n y a pas une grossesse avant de faire une hysterographie

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*Case 2* Woman, aged 20, with a history of menorrhagia and endometritis The patient had been bleeding irregularly for two months and treated with oestrogens and iron The uterus had been of normal size and not tender No pregnancy test was made

Hysterography disclosed that the uterine cavity was relatively large with a coarse and irregular mucosal pattern probably due to endometritis and myometritis The tubes were not filled (Fig 2)

Subsequently, the patient developed fever and pain in the lower part of the back associated with a bloody vaginal discharge Palpation of the uterus now suggested a pregnancy of three months, small portions of placental tissue were protruding through the cervix Evacuation of the uterus was performed Microscopy disclosed material consisting of pus and fragments of pregnant decidua, no villi were visible and there was no evidence of a mole or of malignant proliferation The diagnosis was abortion and endometritis

*Case 3* Woman, aged 32, was admitted with probable abortion in the 4—5 months of pregnancy Two pregnancy tests were negative The uterus was enlarged and a fibroid lay at the fundus

Hysterography disclosed an enlarged globular cavity with a rounded, partly irregular contrast defect close to the wall (Fig 3) The cervix was relatively narrow with no sharp demarcation of the internal orifice The appearances corresponded well to the clinical diagnosis of missed abortion Microscopy after evacuation revealed products of abortion

An aqueous contrast medium consisting of 200 mg iodine/ml was employed in these cases

## Discussion

Abdominal roentgen exposures on women of fertile age are withheld as a routine particularly within the first half of pregnancy Cases of pregnancy will of course appear at intervals and give rise to various problems A pregnancy test would have given the clue in Case 1, and an extensive use of pregnancy tests before hysterography appears most desirable The hysterogram in Case 2 indicated a condition of abortion and infection, the administration of oestrogen over a period may possibly have influenced the picture But for the patient's age the possibility of a villous carcinoma of the corpus might have been considered Case 3 was somewhat typical of missed abortion and hysterography combined with negative pregnancy tests and clinical evidence afforded valuable diagnostic support

## SUMMARY

Three cases of hysterography in connection with intrauterine pregnancy and abortion are presented and the diagnosis is discussed The importance of excluding pregnancy before hysterography is stressed

Two pulsating subcutaneous arteries proved to be too small for arteriography A polythene No 160 catheter was introduced into the draining vein and the contrast medium injected in a retrograde direction (Gidlund pre[illegible] duced in Fig 1b c and d Numer[illegible] whole mass was richly vascularized

The long history and the findings suggested a cystosarcoma phyllodes and the phlebographic appearances consistent with a benign tumour appeared to confirm the diagnosis The tumour was excised locally without difficulty and proved to be a benign cystosarcoma phyllodes No local recurrence and no metastases have occurred five years after the operation

*Case 2* Woman, aged 42, adipose, had 4 weeks prior to admission noticed a non tender tumour in the left breast, which had become enlarged The mass was about the size of an orange and well defined although somewhat irregular with soft alternating elastic and firm areas The skin was slightly streched but not adherent to the tumour The level of the nipple was slightly raised

Some subcutaneous veins were visible but were not dilated, the largest just permitting the introduction of a polythene catheter and the injection of contrast medium (Fig 2) A few normal subcutaneous veins were filled, while the tumour' and its surroundings remained avascular Needle biopsy produced pus like fluid and operation revealed an encapsulated abscess. The absence of any demonstrable vascular connection between the subcutaneous veins and the tumour should possibly have permitted the exclusion of a cystosarcoma The avascularity on the other hand obviously suggested an abscess

## Discussion

Cystosarcoma phyllodes are uncommon fibro-epithelial tumours of the female breast that may occur at any postpubertal age although usually in the fourth decade of life They are related etiologically to the mammary fibroadenomas, with their maximum frequency about ten years earlier Most of the cystosarcomas develop from pre-existing fibroadenomas but there is evidence that they occasionally may also arise de novo, without a precursory tumour The cystosarcomas may vary in size, the smallest may measure about 1 cm, and the largest can be enormous In spite of the term 'sarcoma' nine-tenths of the tumours are clinically innocuous while the remaining tenth behaves like highly malignant mesenchymal tumours, leading to death from general metastases, sarcomatous in character Dilated and tortuous subcutaneous veins over, and in the vicinity of, the medium sized and large tumours may be a prominent feature and are apparently due to the transit of a considerable amount of blood These tumours are thus highly vascularized, in fact most of the growths observed by the author including two that were malignant were found to be rich in vessels The basic conditions for successful angiographic (phlebographic) examinations thus seem to exist

Phlebography in the present case disclosed that the tumour was extremely

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# CYSTOSARCOMA PHYLLODES DIAGNOSED BY SUBCUTANEOUS MAMMARY PHLEBOGRAPHY

by

FRANZ PAUL PROBST

The diagnosis of tumours or tumour like conditions of the female breast rests essentially on the histologic or cytologic examination of material obtained by excisional, incisional or needle biopsy The only roentgenologic contribution of importance to the diagnosis of these lesions is mammography, a method not in general use However, one of the cases now reported indicated that one kind of bulky tumour of the breast is accessible to the angiographic diagnosis the cystosarcoma phyllodes The value of subcutaneous mammary phlebography is further demonstrated in the second case in which the 'tumour' was clinically indistinguishable from a cystosarcoma

## Case reports

*Case 1* Unmarried woman, aged 29 years, who for 8 years had been aware of a lump in the right breast, the size of which had remained unchanged About 3 months prior to admis sion the tumour commenced gradually to increase in size The patient had no other symp toms On examination, the right breast was larger and more pendulous than the left A lobated tumour, about 9 cm in diameter, lay centrally in the breast The tumour was rela tively soft in some parts and firm or elastic in others, it was not attached to the pectoralis fascia or the overlying skin Several enlarged veins covered the mass, these were drained by a vein that disappeared in the upper parasternal region (Fig 1a)

Submitted for publication 28 August 1969



Fig 2 Case 2 Mammary abscess subcutaneous mammary phlebography The mass is avascular and thus probably not a cystosarcoma

vascular and had defined borders The sharpness of its delimitation, particularly against the thoracic wall, is of importance from the prognostic and surgical point of view, since it excludes an infiltrative growth into the surroundings and facilitates planning of the operation However, the angiographic features cannot permit the exclusion of possible malignancy as malignant foci within such tumours may be small and difficult to detect even on careful histologic examination of the entire tumour It is impossible to say anything about the 'specificity' of the angiographic features as no other cases examined by this method exist However, it appears not unlikely that other cystosarcomas may behave in a similar manner If further experience should indicate that phlebography of cystosarcomas is pathognomonic, the need for biopsy may be avoided and the risk of dissemination in those cases that harbour malignant tissue diminished

Fig 1 Case 1 Cystosarcoma phyllodes a) Tumour in the central part of the right breast changing its contour large subcutaneous veins are present b) c) and d) Subcutaneous mammary phlebography Dense network of intratumoral veins surface veins radiate towards larger collecting vessels which are drained by one large and several small efferent veins Optimal tangential view (d) defines a sharp border of the tumour against the thoracic wall and indicates no infiltration into the wall



a



b



c



d

Fig 1 (for legend see opposite page)

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# ORAL CHOLECYSTOGRAPHY

## Experimental investigation and clinical comparison of 70 mm film and full scale radiography

by

RAGNAR JENSEN and JURI KAUDE

In oral cholecystography compression spot films under fluoroscopic control usually project the gall bladder free from overlying intestinal gas It may be necessary to obtain additional supine or prone films with the overhead tube or with horizontal beam and patient in the right decubitus position A correct diagnosis with the conventional method can be established in approximately 93 to 98 % of cases (JOHNSON & HARREL 1935, GOOD & KIRKLIN 1937, OLSSON 1939 WICKBOM & RENTZHOG 1955 BAKER & HODGSON 1958, ALDERSON 1960 and others)

Fluorography with 70 mm film from the output screen of the image intensifier may replace full scale spot films in many roentgendiagnostic procedures (SAMUEL & SUMERLING 1964 WOHL & KOEHLER 1965, ELMER 1967, KAUDE 1967, 1968, COLLARD 1969 KAUDE & REED 1969 KAUDE & SUSHER 1969, and others) The methods has been considered diagnostically inadequate in oral cholecysto-

Part of this work was carried out at the University of Florida College of Medicine where J K acted as Visiting Assistant Professor 1967—1968 Submitted for publication 16 December 1969

## SUMMARY

Two cases of lesions of the breast examined by subcutaneous mammary phlebography are reported. In one case the lesion contained numerous pathologic vessels and proved to be a cystosarcoma, and in the other the mass was entirely avascular and was produced by an abscess. The significance of vascularization and the value of angiography are discussed.

## ZUSAMMENFASSUNG

Zwei Fälle von Läsionen der weiblichen Brust, die mit subkutaner Phlebographie untersucht wurden, werden beschrieben. Die Läsion in einem der Fälle hatte zahlreiche abnormale Gefässe und erwies sich als ein Zystosarkom, im zweiten Falle war die Läsion völlig avaskulär und war durch ein Abszess verursacht worden. Die Bedeutung der Vaskularisation und der Wert der Angiographie werden diskutiert.

## RÉSUMÉ

Présentation de deux cas de lésion du sein examinées par phlébographie mammaire sous-cutanée. Dans un de ces cas, la lésion contenait de nombreux vaisseaux pathologiques et se révélait être un cystosarcome phyllode. Dans l'autre cas la masse était entièrement avasculaire et était produite par un abcès. L'auteur examine l'intérêt de la vascularisation et la valeur de l'angiographie pour le diagnostic.

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# ORAL CHOLECYSTOGRAPHY

## Experimental investigation and clinical comparison of 70-mm film and full-scale radiography

by

RAGNAR JENSEN and JURI KAUDE

In oral cholecystography, compression spot films under fluoroscopic control usually project the gall bladder free from overlying intestinal gas. It may be necessary to obtain additional supine or prone films with the overhead tube or with horizontal beam and patient in the right decubitus position A correct diagnosis with the conventional method can be established in approximately 93 to 98 % of cases (JOHNSON & HARREL 1935, GOOD & KIRKLIN 1937, OLSSON 1939, WICKBOM & RENTZHOG 1955, BAKER & HODGSON 1958, ALDERSON 1960, and others)

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graphy and inferior to full-scale radiography (ELMER 1967, BECKING & HUPSCHER 1968, LINDQVIST 1969), or else the use of 70-mm fluorography has not been recommended in expectance of further improvements in the quality of image intensifiers (COLLARD 1969) However, exact experimental or clinical comparisons of 70-mm fluorography and full scale radiography in examinations of the gall bladder, using geometric or electronoptic magnification, have not earlier been presented

The main advantages of 70 mm fluorography over full-scale radiography — the short exposure time and the low doses to the patient — are not so important in cholecystography, with little or no movement in the object and a small field well removed from the gonadal region However, 70 mm fluorography in oral cholecystography becomes increasingly interesting with the use of remotely controlled diagnostic equipment (JUTRAS & DUCKETT 1958, FEDDEMA 1960 1962, 1965, and others) and with fluoroscopic-fluorographic equipment without interposed full scale spot film holder (KAUDE 1968, FENZ 1969, HODGES & KAUDE)

As a link in a series of comparisons of full scale radiography and 70 mm fluorography, we have investigated the diagnostic accuracy of the latter in experimental studies with a gall bladder phantom, using a small focal spot and geometric and electronoptic magnification, and compared the method with full-scale radiography at oral cholecystography in routine clinical work

*Equipment* Both the experimental and clinical investigations were performed with two different types of equipment

With the use of a three-phase generator and a remotely controlled ring stand the focal spot was 0 6 mm Spot films were obtained from the output screen of a 23 cm/12 5 cm (9″/5″) image intensifier with a Philips 70 mm camera at 60, 70, 80, 90 and 100 kV (in clinical work usually at 70 to 90 kV) Exposure control was automatic The 70-mm fluorograms were made on Gevaert Scopix HD film Using a processor of roll type (Profexray), the films were developed at 78° F in Du Pont D-90 for 75 seconds to a gamma of about 1 1 to 1 2 The total processing time was 5 minutes and 15 seconds Full-scale roentgenograms were made on Gevaert Curix RP films (acetate base) with Siemens Safir universal screens and processed in Kodak RP X Omat The time of development in the latter was one minute at 99° F The total processing time for full scale roentgenograms was adjusted to 3 minutes

Fluoroscopy was performed with a transistorized Plumbikon television chain at 60 to 100 kV and 0 5 to 2 mA Videofluoroscopy and filming with both methods were carried out at 1 3 times geometric magnification, 70 mm fluorography and fluoroscopy were also performed with 1 8 times geometric

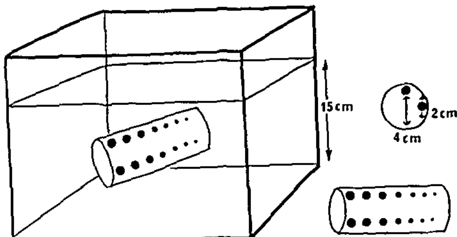



Fig 1 The gall bladder phantom placed in 15 cm water

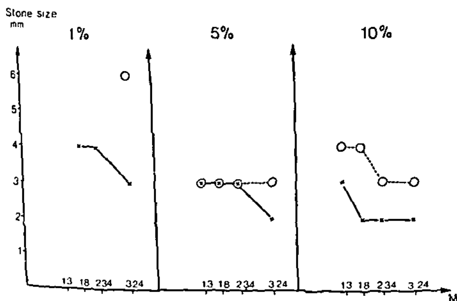



Fig 2 Smallest detectable stone size at videofluoroscopy with 0 6 mm focal spot and 23/12 5 cm image intensifier at different concentrations of contrast medium in the gall bladder

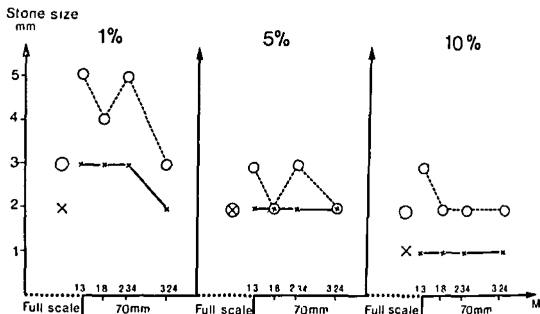



Fig 3 Smallest demonstrable stone size with 0 6 mm focal spot and 23/12 5 cm image intensifier The total magnification (M) was 1 3 geometric only for full-scale The curves represent for 20 mm contrast medium, full-scale (X) and 70-mm film (x——x), for 40 mm contrast medium, full-scale (O) and 70-mm film (o - - - - - - o)

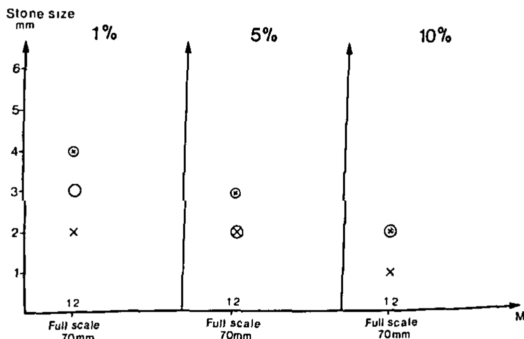



Fig 4 Smallest demonstrable stone size with 1 0 mm focal spot and 15 cm image intensifier The magnification was 1 2 geometric The curves represent for 20 mm contrast medium, full-scale (X) and 70-mm film (x), for 40 mm contrast medium, full scale (O) and 70 mm film (o)

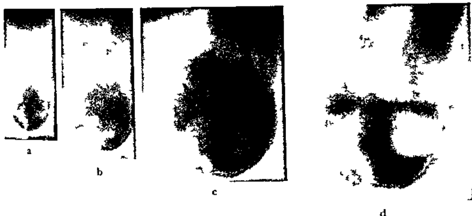



Fig 5 Two stones in a gall bladder with high concentration of contrast medium a) 70 mm film 1 3 geometric magnification b) 70-mm film 1 8 geometric magnification c) 70-mm film obtained with 3 24 total magnification (1 8 geometric × 1 8 electronoptic) d) Full scale film

magnification and with additional electronoptic magnification (total enlargement 2 34 or 3 24 times, respectively)

This type of equipment is not available in all roentgendiagnostic departments, or a 15 cm (6″) image intensifier may be preferred to a 23 cm intensifier Practical considerations may also require that only one type of processor be used for films of all sizes Experimental and clinical investigations were therefore carried out also with a single phase 500 mA generator and a 1 mm focal spot with the least possible (1 5 to 1 2 times) geometric magnification The 70 mm films were then made on Kodak Linagraph Shellburst (Estar base emulsion No 2474) or Kodak X Omat Fluorospot film The full scale roentgenograms were obtained with overhead tube and Bucky diaphragm on Kodak RP-54 film, using medium speed screens In this series, films of both sizes were processed in the Kodak RP X Omat in 90 seconds

## Experiments

*Method* A cylindric perspex container (length 120 mm, diameter 40 mm) simulated a normal sized gall bladder Common, mixed type cholesterol, bile pigment and calcium salt stones, radiographically equivalent to water, were attached to the wall of the container at its greatest diameter (40 mm) and at a diameter of 20 mm (Fig 1) With this placement of stones, cholesterol polyps, or calculi, floating in an ordinary gall bladder and in a compressed or small

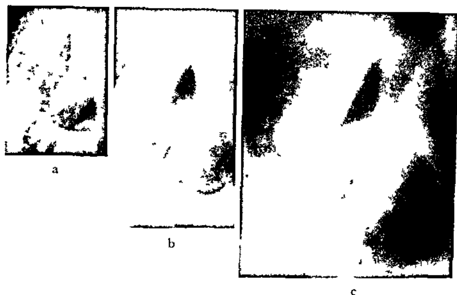



Fig 6 Gall bladder filled with small calculi, patient supine right posterior oblique position 70 mm films with following magnifications a) 1 3 geometric, b) 1 8 geometric c) 3 24 total magnification (1 8 geometric × 1 8 electronoptic) The stones are better demonstrated in b) and c)

gall bladder were simulated The sizes of the stones in both rows were 1, 2, 3, 4, 5 and 6 mm

Two types of water-soluble contrast media were used to fill the gall bladder phantom *Cystokon (Mallinckrodt Pharmaceuticals, St Louis) and Isopaque* Cerebral (Nyegaard, Oslo) The contrast media were diluted to 1 %, 5 % and 10 % concentrations The 10 % contrast medium simulated best the density produced in oral cholecystography (STAPLE & McALISTER 1965) The gall bladder phantom filled with the 1 % contrast medium was barely visible at videofluoroscopy In clinical work, a gall bladder with such a low concentration of contrast medium and without demonstration of stones would have to be reexamined

The gall bladder phantom was placed in a 15 cm high water phantom which simulated the soft tissues of an average patient The primary collimation was the same as in clinical work The field was reduced to include the gall bladder phantom with a narrow edge of water

*Results.* The size of the smallest stone observed by the authors at fluoroscopy, or demonstrated with full-scale radiography and 70-mm fluorography, depended upon the contrast medium concentration in the gall bladder phantom and the magnification used The perceptibility, in particular of stones in low contrast, was improved by the use of magnification techniques (Figs 2, 3 and 4)

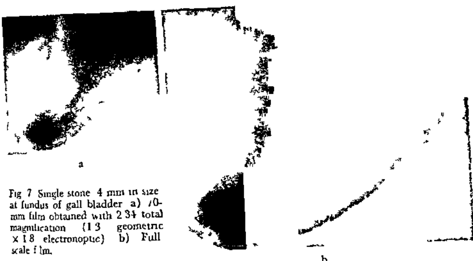


Fig 7 Single stone 4 mm in size at fundus of gall bladder a) 70-mm film obtained with 2 34 total magnification (1 3 geometric × 1 8 electronoptic) b) Full scale film.

## Clinical comparison

*Material and Method* Both full scale and 70 mm films were employed as a routine at the same session in 400 non-selected cases the gall bladder being filled with contrast medium and observed at videofluoroscopy A total of 325 cases were examined at Lund and received eight tablets of Biliodon Natrium (sodium salt of iopanoic acid, AB Leo, Halsingborg) The Gainesville material included 75 cases which were given 6 to 12 tablets of Telepaque (brand of iopanoic acid, Winthrop Laboratories, New York)

Excessive colon gas was eliminated by the intramuscular injection of 10 international units of vasopressin (COLLINS & ROOT 1936, GOTHLIN 1969)

The authors of the present paper reviewed both the 70 mm and the full-scale cholecystograms without knowledge of the conclusion made at the primary routine interpretation Because our investigation aimed at an evaluation of the diagnostic accuracy of the 70 mm technique, the small films were interpreted first a diagnosis was made, and then the full scale films were read All the examinations included in the series were technically of good quality and diagnostically conclusive A magnifying viewer (MATTSSON 1953) was used with the 70 mm films in order to eliminate scattered light The findings at operation became available for comparison in a number of cases

*Results* A total of 322 of the 400 oral cholecystographies performed both with 70-mm fluorography and full scale radiography were normal Biliary

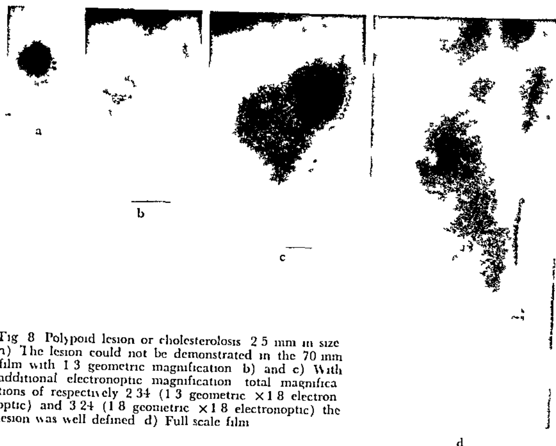



Fig 8 Polypoid lesion or cholesterolosis 2 5 mm in size a) The lesion could not be demonstrated in the 70 mm film with 1 3 geometric magnification b) and c) With additional electronoptic magnification total magnifications of respectively 2 34 (1 3 geometric × 1 8 electron optic) and 3 24 (1 8 geometric × 1 8 electronoptic) the lesion was well defined d) Full scale film

calculi were diagnosed in 72 cases, polypoid lesions or cholesterolosis in 5 cases and adenomyosis of the gall bladder in one case The interpretation of the film of both sizes were in agreement in 398 cases (99 5 %)

There was disagreement of interpretation in two cases (0 5 %), both examined with the 23/12 5 cm image intensifier Four stones, 1 to 2 mm in size, were not observed in the 70 mm films, these being superimposed upon the 12th rib In comparison with the conventional films, the 70 mm films had been obtained in slightly different projections and slightly different degrees of compression A further inspection of the films just revealed the stones, however This finding was the only erroneous one made in relation to the 70 mm films The patient later developed cholecystitis and at repeat examination no contrast filling of the gall bladder was obtained Operation took place 2 years after the initial examination and the stones were then about 3 to 4 mm in size In the second case, a 3 mm polypoid lesion in the gall bladder was thought to be present in the full scale films This was not seen in the 70 mm fluorograms The diagnosis at the routine interpretation of the full scale roentgenogram had been normal

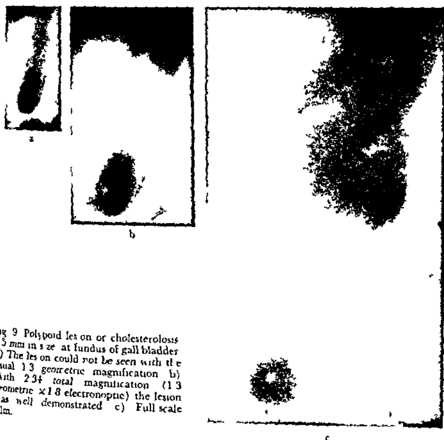



Fig 9 Polypoid lesion or cholesterolosis 2.5 mm in size at fundus of gall bladder a) The lesion could not be seen with the usual 1 3 geometric magnification b) With 2 34 total magnification (1 3 geometric ×1 8 electronoptic) the lesion was well demonstrated c) Full scale film.

cholecystogram' At the *repeat reading it* became evident that the filling defect was a *small* gas bubble in the colon which lay over the gall bladder

Figs 5 to 9 present the findings in the comparison of 70 mm fluorography and [illegible] [illegible] ie examinations have [illegible] low contrast and the [illegible] of *employing* magnification techniques with 70 mm fluorography The 70-mm *films* are reproduced in their original *size*

## Discussion

It is evident that biliary calculi can often be diagnosed at *videofluoroscopy* (Fig 2) From a *practical* point of view, 70 mm filming is sufficient for documentation in such cases. The *fluoroscopic* diagnosis is improved when




Fig 10 Gall bladder filled with stones up to 5 mm in size in 70 mm films obtained with 1 mm focal spot and 15 cm image intensifier using about 1 2 geometric magnification a) Erect b) Supine RPO film

magnification techniques are used, and this is particularly important when the contrast is low In a 40-mm column of the 1 % contrast medium at phantom studies, only the largest stones (6 mm) could be seen, and then only when electronoptic magnification was applied simultaneously with 1 8 times geometric magnification (total magnification 3 24 times)

The lower size limit for a detail that can be demonstrated with 70 mm films in clinical examinations with a water-soluble contrast medium is approximately one millimeter (BÅNG & KAUDE 1967) Stones of this size were the smallest tested and observed in studies with the gall bladder phantom It was also shown that with the use of a 0 6 mm focal spot and geometric and electronoptic magnification, mixed-type gallstones could be demonstrated with the 70 mm technique to the same extent as with full-scale radiography (Fig 3)

In a recent comparison of 322 oral cholecystograms obtained with both 70-mm fluorography and conventional radiography, LINDQVIST (1969) reported, however, that in ten cases (3 %) the diagnosis with 70 mm films was either erroneous or doubtful In the present comparison, only one 70-mm examination, out of 400 cholecystograms, was misinterpreted and four stones 1 to 2 mm in size were not diagnosed On the other hand, one examination performed with the full-scale technique (colon gas thought to be a polypoid lesion in the gall bladder), was incorrectly interpreted This report was corrected at reviewing

The difference in results between the study by LINDQVIST (1969) and the present comparison must depend on a difference in examination techniques at 70-mm fluorography The focal spot in both investigations was 0 6 mm but LINDQVIST did not utilize geometric magnification because with the apparatus

available to him compression could not be applied because of the increased distance between the patient and the input screen of the image intensifier Nor had he access to an image intensifier permitting electronoptic magnification, the field size was also not reduced to a possible minimum by primary collimation

Each of the these three factors is of great importance for the improvement of the image quality in 70 mm fluorograms Figs 3, 8 and 9 indicate that in some cases the demonstration of small polypoid lesions or stones is not possible without magnification techniques

Geometric magnification diminishes scattered radiation and improves the contrast and the resolution (FEDDEMA 1962, 1965, HOLM 1962, 1964, FEDDEMA & BOTDEN 1965) A small focal spot (0 6 or preferably 0 3 mm) is needed for geometric magnification Electronoptic magnification reduces quantum noise and improves the resolution because an increase in the radiation of about 3 2 to 3 3 times is needed for this technique (HELLEKAMP & ENDLICH 1965, KUHL & VAN OVERHAGEN 1965, FEDDEMA 1965) Because the field size is diminished, this increase of the radiation still does not result in an increase of the integral absorbed dose (FEDDEMA 1965)

By the simultaneous use of both magnification techniques the advantages are added and the object is moreover recorded in nearly its original size

Finally a careful collimation of the field improves image quality and contrast by reducing not only scattered radiation but also unnecessary light scatter inside the image intensifier (BERANBAUM & LIGNON 1964, FEDDEMA 1965, MARQUERINCK & RECOURT 1965) The importance of a small field size and focal spot in the diagnosis of biliary calculi in full scale radiography has been well documented by VIRTAMA (1961) The effective use of primary collimation is even more important in a more sensitive recording system requiring a low exposure such as 70 mm fluorography

No diagnostic errors were made in the series of 75 cases examined with a 1 0 mm focal spot and 15 cm (6 ) image intensifier (Fig 10) However, the smallest stones in this series were at least 2 to 3 mm in size and thus corresponded to the size of the smallest stones that could be demonstrated in phantom studies with the same equipment (Fig 4)

It is important to reduce focal unsharpness and to decrease the distance between the patient and the input screen of the image intensifier as much as possible with a focal spot of 1 0 mm or larger This is more effectively accomplished when the interposed full scale spot film holder is removed HODGES & KALDE KALDE 1968)

The importance of compression for equal distribution of contrast in the gall bladder (OLSSON 1939) is evident from Figs 2 to 4 The stone size demonstrated in films or observed at videofluoro copy was smaller when the stone was placed

in a 20-mm column than in a 40-mm column of contrast medium. Compression should consequently be applied even when geometric magnification is used to improve the detection of small stones.


## Acknowledgement

The authours are indebted to Mr. Lloyd M. Geyer of the S. and H. X-ray Company, Atlanta, Georgia, for his interest in this project and for help in the experimental investigations carried out at Gainesville.



## SUMMARY

*The diagnostic accuracy of 70-mm fluorography in examination of the gall bladder was investigated with the aid of a phantom and in a series of 400 oral cholecystographies.* Biliary calculi and polypoid lesions could be demonstrated with 70 mm fluorography as accurately as by full scale radiography. The demonstrable stone size was inverse to the concentration of the gall bladder contrast.

## ZUSAMMENFASSUNG

Die diagnostische Genauigkeit des 70 mm Bildverstärker-Aufnahmeverfahrens bei Untersuchung der Gallenblase wurde mit Hilfe eines Phantoms und in einer Serie von 400 oralen Cholezystographien verwertet. Gallensteine und polypoide Veränderungen in der Gallenblase konnten mit 70 mm Technik mit derselben Genauigkeit wie mit Grossformat-Aufnahmeverfahren nachgewiesen werden. Die demonstrierbare Steingrösse stand im umgekehrten Verhältnis zu der Konzentration des Kontrastmittels im Gallenblasenphantom.

## RÉSUMÉ

Les auteurs ont étudié la précision diagnostique de la radiophotographie en 70 mm dans les examens de la vésicule biliaire au moyen d'un fantome et sur une série de 400 cholécystographies par voie orale. Ils ont pu mettre en évidence les calculs biliaires et les lésions polypoïdes avec autant de précision au moyen de la radiophotographie en 70 mm qu'au moyen des radiographies en vraie grandeur. Le diamètre des calculs que l'on peut mettre en évidence varie en sens inverse de la concentration du moyen de contraste dans la vésicule biliaire.


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# OCCURRENCE AND COURSE OF THROMBOSIS FOLLOWING PROSTATECTOMY

## A phlebographic investigation

by

J BECKER, S BORGSTRÖM and G F SALTZMAN

It was long considered that the clinical signs of acute thrombosis of the lower limbs were so characteristic that a correct diagnosis could be made with a high degree of certainty In an increasing number of publications, however, the infallibility of the clinical diagnosis is being questioned It has now become obvious that if the clinical evidence alone is used as the basis for diagnosis, a great many cases of thrombosis will be missed and furthermore a considerable degree of overdiagnosis will occur Effectively performed phlebographic examinations have been the main agents in revealing the inadequacy of the clinical diagnosis

Most of the reports on phlebographic investigations dealing principally with the diagnosis of thrombosis have, it is true, demonstrated incomplete *agreement* between the clinical signs and phlebographic findings, but they can hardly be said to have increased the possibilities of assessing the incidence of thrombosis or of studying the course of a thrombosis already diagnosed *The reason for this is* that in nearly all cases some form of clinical manifestation has been the indication

Submitted for publication 18 September 1969

for the phlebographic examination Only a few investigations have been described in which phlebography was carried out routinely in thrombosis prone materials (post traumatic cases) irrespective of whether clinical signs of thrombosis were present or not (BORGSTROM et coll 1965 1967, BERGVALL & HJELMSTEDT 1968 FREEARK et coll 1967) These materials clearly reveal that thrombosis producing no clinical signs or symptoms is not uncommon and that the thrombotic condition may be localized either to deep veins or to muscle veins

The subsequent course of thrombosis has been studied by phlebography by only a few workers, and in those cases in which this has been done the main object has been to investigate the effect of different forms of therapy MAY & NISSL (1959) and BERGVALL & HJELMSTEDT (1968) studied the recanalization process in deep vein thrombosis The phlebographic appearances of post thrombotic changes have been described in some detail It is considered that in most perhaps even in all cases, the condition leaves phlebographically demonstrable post thrombotic changes (HAEGER 1965) No conclusive arguments to prove such a view seem to have been advanced however

It is now universally recognized that certain types of traumatic damage and surgical interventions predispose to the development of thrombosis It is generally a question of elderly patients who in the nature of things already run an increased risk of developing the condition It therefore seems likely that in some of the cases of thrombosis that have been diagnosed postoperatively the condition was present prior to the intervention Pre operative and postoperative phlebographies for purposes of comparison do not seem to have been carried out and it is thus not surprising that the views regarding the phlebographic appearances in acute venous thrombosis should be highly divergent (NYLANDER 1968, BORGSTROM et coll 1965, and others)

With these unsolved problems in mind a series of phlebographies were set up in connection with attempts to achieve better thrombosis prophylaxis following prostatectomy The problems investigated were (1) the thrombosis rate that could be demonstrated by phlebography after prostatectomy, (2) the location of the thrombi, (3) the extent to which the thrombi produced post thrombotic venous changes and the appearances of these changes, and (4) how often the thrombi diagnosed postoperatively were present before the intervention

*Material* The total material consisted of phlebographies performed on 367 legs in 187 cases It was compiled in connection with different experimental series set up in attempts to improve the thrombosis prophylaxis The observations relevant to the latter problem are to be published in another connection (BECKER et coll 1969) As no differences at all could be found in the incidence of thrombosis between the experimental series, either among the series themselves or

between the different series and control groups, the material has been treated as a unit

All the examinations were made in connection with transvesical prostatectomy, and the material may thus be considered homogeneous not only in regard to factors predisposing to acute thrombosis but also to the age distribution among the patients

Phlebography was always performed a short time after the operation, a bilateral examination was planned for all cases and in most instances could also be carried out When no clinical signs of thrombosis existed, the phlebographies were performed not later than one month after the prostatectomy, most examinations were made within one to two weeks In cases with clinically probable thrombosis, phlebography was carried out at once

A follow up examination was performed in nearly all the cases in which thrombosis was present at the first postoperative phlebography, the interval between this and the earlier phlebography ranged from two months to two years. It was occasionally not possible to carry out a second examination

Pre-operative phlebography was also performed on 110 legs in 56 cases. This was done in order to gain information on the incidence of pre-operatively manifest thrombosis as well as to be able to assess the course of any thrombosis that arose postoperatively in relation to the pre-operative status

*Methods* All the examinations were performed in accordance with the method of ascending phlebography first introduced by GREITZ (1954) The method has been used by BORGSTROM et coll (1965) for thrombosis studies A brief recapitulation of the technique will be given

The patient is examined in a semi erect position A dorsal vein of the foot is punctured percutaneously and 60 ml Urografin 45 % are rapidly injected Films are exposed in two planes and cover the crus and a part of the thigh The upper part of the thigh is examined only in the a p projection This series is repeated so that two roentgenograms are exposed in each projection No elastic bandage is used

Thrombi appear as defects in the contrast filled veins As ALMEN & NYLANDER (1964) have demonstrated, not all contrast defects in veins are caused by thrombi BORGSTROM et coll have set up criteria that should be observed before a diagnosis of thrombosis is justified We have found these to be adequate and have used them when diagnosing the condition Briefly, they imply that the contrast defects should be distinctly demarcated, that they must have identical appearances in views taken at varying intervals after contrast injection, and that they must be visible in two different projections. All cases in the present material judged to have thrombosis fulfilled these requirements For considera-

tions of space, examples of this have not been given in the illustrations but views giving information with more relevance to the questions studied in this paper have been included

## Results

The phlebograms were studied first from the aspects of the thrombosis rate and the site of the thrombi The *subsequent course of the disease was also in*vestigated An attempt was made in a small series to assess the significance of thrombi present pre operatively as a possible source of error in the evaluation of thrombosis arising postoperatively

*Thrombosis rate* Clinical signs of thrombosis were present in 19 cases (10 %) This rate tallies with the figures given for earlier series in which the assessment had been made on the basis of the clinical signs following prostatectomy Phlebo graphic examination revealed thrombosis in 51 legs (14 %) in 39 cases (21 %) In one case, muscle vein thrombosis seemed highly probable but the contrast defect did not meet all the criteria that had to be observed There was thus a definite discrepancy between clinical signs and phlebographic findings

*Only thirteen of the nineteen cases with clinical signs of the disease* were verified as cases of thrombosis at the phlebographic examination In one other case, a defect that suggested thrombosis was seen in a muscle vein but it did not meet all the criteria necessary for a definite diagnosis In five cases there were no signs at phlebography to indicate thrombosis

Clinically characteristic signs of pulmonary embolism were observed in three cases Two of these patients died and necropsy confirmed the diagnosis of *pulmonary embolism in both of them* These two cases require further comments In one of them, bilateral phlebography 8 days after operation revealed nothing to suggest thrombosis The patient died 13 days after the roentgen examination, and necropsy disclosed in addition to pulmonary embolism large thrombi in the femoral veins In the other case, thrombotic changes in a muscle vein and a superficial vein (thrombophlebitis) were observed at phlebography 5 days after the intervention The patient died 16 days after the roentgen examination and necropsy confirmed the presence of muscle vein thrombosis in addition to the pulmonary embolism, but it also revealed wide spread thrombosis of the femoral vein and pelvic veins on the same side

In 166 cases there were no clinical signs of thrombosis but 26 of these proved to have phlebographically *demonstrable thrombi during the postoperative* course In twenty four of the latter the condition was disclosed at the routine post operative phlebographic examination In addition one other case with a mus le




Fig 1 a) and b) Two small thrombi in muscle veins (→) demonstrated 15 days after prostatectomy c) and d) Total regression 6 weeks later

vein thrombus in a clinically symptom free leg had clinical signs of, and phlebographically confirmed thrombosis in the other leg

It was stated under the heading material that the time interval between operation and routine postoperative phlebographies varied in the cases without clinical signs but that the longest interval was one month An attempt was made to divide this material in different ways into cases with early' and late' phlebographies No significant differences were found between these groups It should be mentioned however that in two cases with negative phlebograms 9 and 16 days respectively after operation, extensive deep vein thrombosis was established later The condition was diagnosed at phlebographies undertaken later because of clinical signs of thrombosis In one case the diagnosis was made four and a half months after operation, in the other case deep-vein thrombosis was present just over one month after the intervention and at further phlebography a few months later it had progressed

No difference in thrombosis frequency in relation to age was noted in this material The average age of patients with and without thrombosis was almost identical 70 and 69 years respectively



Fig 2 a) Thrombus in muscle vein (→) demonstrated 13 days after prostatectomy b) Total regression 3 1/2 months later

*Site and distribution of thrombosis* The site and distribution of the thrombi were investigated in the fifty one cases in which thrombosis was diagnosed by phlebography

In most of the cases (47 legs) *thrombi* were present in the muscle veins of the *lower limbs* (Figs 1 to 5) and in 11 of these legs there were also thrombi in the deep venous stems in addition to those in the muscle veins Thus, muscle vein thrombosis alone was observed in 36 legs

Isolated thrombus formation in one of the deep venous stems was noted in only four cases (Figs 7 and 8) None of these deep thrombi blocked the affected vessel completely, the contrast medium could always pass to one side of it Not a single case was observed in this material in which all the contrast medium presumably passed through superficial veins

In two of the cases in which the thrombi were classified as lying in deep venous stems their relations to the popliteal vein were such that they were interpreted as originating in all probability in the short saphenous vein (Fig 11)

In order to see whether there was any relation between the site of the thrombi and the clinical signs of thrombosis the cases were divided into two groups Clinical manifestations were present in 10 legs with phlebographically confirmed pure muscle vein thrombosis, while in 26 cases with pure muscle vein thrombosis there were no clinical signs at all Of the ten cases with clinical manifestations, nine had local signs in the legs, while one patient died of pulmonary embolism without having any leg signs




Fig 3 Muscle vein thrombosis (→) demonstrated 13 days after prostatectomy (b) Two months later (c) the thrombosed vein has resumed the appearances seen at pre operative phlebography (a)

Five among the fifteen cases with deep venous thrombosis with or without thrombi in muscle veins had clinical signs, these were in the legs in four instances and in the fifth the patient died of pulmonary embolism

Thus, in this material clinical signs were present three times more often in cases with thrombosis of the deep venous stems than in those in which the condition was confined to the muscle veins, although even in the former they were not common

*Further course of acute postoperative thrombosis* Additional phlebographies were performed in 40 cases in order to study the subsequent course of acute postoperative thrombosis that had been confirmed by phlebography In the other cases with thrombosis, such an examination could not be carried out, either because of death from pulmonary embolism, death from some other cause, refusal on the part of the patient to submit to another examination, or failure in the attempts to perform further phlebography

The time interval between the repeat phlebography and the examination at

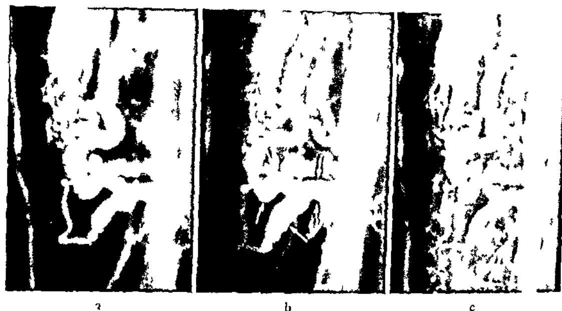



Fig 4 Muscle vein thrombosis (→) demonstrated 17 days after prostatectomy (b) Three months later (c), the thrombosed *veins have resumed* the appearances demonstrated at pre operative phlebography (a)

which thrombosis had been diagnosed varied considerably The shortest period was three weeks and the longest nearly two and a half years, with an average of thirty-three weeks

The results obtained from the further phlebographies showed considerable *variations* Total regression, with an apparently completely normal venous system, was observed in *sixteen legs*, while twenty-four phlebograms presented different types of pathologic changes in the veins These variations seem to justify a closer *analysis*

A *Total regression of fresh thrombi* Among the sixteen cases in which the thrombi had disappeared without leaving any traces there were cases both of muscle vein thrombosis (Figs 1 to 4) and of thrombi in the deep venous stems (Figs 7 and 8) Total regression of deep-vein thrombosis occurred in seven cases This *figure means* that total regression of fresh thrombi in deep venous stems was definitely more common than complete disappearance of such thrombi in muscle veins Valves that appeared completely normal were observed in many of the previously thrombosed deep veins (Figs 7 and 8) The veins had in most cases decreased in diameter after the thrombus had disappeared The time interval between the two postoperative phlebographies in these cases with total regression varied between four weeks and one and a half years, with an average of five months The patient in whom this regression occurred as early as four weeks after

the first examination had had thrombi both in muscle veins and in a deep venous stem The thrombi had disappeared within three months of the time when they were diagnosed in 8 cases, in other words half the number with total regression

Clinical signs of thrombosis were present in only two of these sixteen cases when the condition was diagnosed by phlebography. It was in both instances a question of thrombi in deep veins of the lower limb, in one of which muscle-vein thrombosis was also present

It may be worth mentioning in this connection that heparin therapy had in most cases been instituted as soon as a thrombus was detected This was omitted in four cases but total regression occurred in three of them

dangerous to describe vessels that have been the seat of blood clots as completely normal The evidence can hardly be regarded as conclusive unless pre-operative phlebography has been performed This question will again be considered when describing the series in which both pre- and postoperative examinations were carried out

B *Persisting pathologic venous changes after acute thrombosis* Cases of both muscle vein and deep-vein thrombosis were encountered among the twenty-four legs in which some form of change was still present at repeat phlebography The number of legs with thrombi in muscle veins was eighteen, while in six legs thrombi in deep venous stems as well as in muscle veins had been demonstrated

The time interval between the two postoperative phlebographies varied in this group from three weeks to about two and a half years, with an average of ten months Thus, the period was on an average twice as long as in the group with total regression of verified thrombosis

The persisting pathologic changes may be divided into smaller groups.

1 *Irregular vein wall* No thrombus remnants were seen in the relevant vein in eleven legs at the second phlebography although the venous walls were clearly irregular (Fig 5) The severity of these changes varied, in some instances they were so slight that it is doubtful whether they would have been noticed if it had not been known that the vein had previously contained a thrombus. These affected veins were as a rule narrower than at the examination when the thrombus was detected Apparently normal valves were observed in two cases

2 *Persisting thrombus remnants* Small remnants were present in six legs at the second postoperative phlebography (Fig 6) The thrombus had in every instance decreased to a fraction of its original size, the vein walls were noticeably irregular in all these cases Apparently normal valves were present in one case in a previously thrombosed part of a vein




Fig 4 Muscle vein thrombosis (→) demonstrated 17 days after prostatectomy (b) Three months later (c), the thrombosed veins have resumed the appearances demonstrated at pre operative phlebography (a)

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The results obtained from the further phlebographies showed considerable variations Total regression, with an apparently completely normal venous system, was observed in sixteen legs, while twenty four phlebograms presented different types of pathologic changes in the veins These variations seem to justify a closer analysis

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Fig 7 a) Deep-vein thrombosis (→) demonstrated 18 days after prostatectomy b) Total regression 2 years later The valves in the thrombosed area are apparently normal

thrombosed venous segment had become noticeably larger but part of the previously thrombotic area in the respective vein was now free from clots In the third case, the thrombus observed at the first examination had disappeared but had left signs of vein wall irregularity A further thrombus in a muscle vein had however developed in a vein that had presented no evidence of involvement at the first examination

*Comparison between pre and postoperative phlebographies* The need for pre-operative phlebographies became increasingly apparent as the investigation proceeded Two questions in particular demanded an answer, viz if all the thrombi demonstrated after the operation had really arisen postoperatively, or if some of them had been present earlier, and, further, whether the condition interpreted as total regression of a thrombosis was a complete return to the prethrombotic venous anatomy

A total of 110 pre operative phlebographies were therefore carried out in cases in which it was intended later to perform postoperative phlebography The pre-operative examination was usually performed a week before the operation Any thromboses detected were also examined by further phlebographies Although the material is small, a few observations seem worth mentioning

Ninety four of these pre-operative phlebographies could be used for a comparative study, as the examination series could be followed through in these cases. Postoperative thrombosis arose in eleven of these legs, in four of them the thrombi disappeared completely and the veins reverted to exactly the same appearances

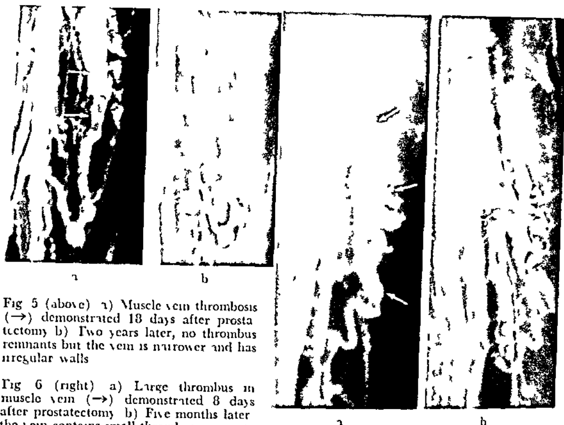


Fig 5 (above) a) Muscle vein thrombosis (→) demonstrated 18 days after prostatectomy b) Two years later, no thrombus remnants but the vein is narrower and has irregular walls

Fig 6 (right) a) Large thrombus in muscle vein (→) demonstrated 8 days after prostatectomy b) Five months later the vein contains small thrombus remnants (↣) and is narrower

As these thrombus residues might conceivably represent a phase in development towards further regression, the time interval between the phlebographies was investigated In two instances the period was short (three and six weeks respectively) so that the possibility of continued regression cannot be excluded In the other four cases, the period was much longer, namely three and a half months, just over five months, one year, and nearly two and a half years, respectively

3 *Progress of thrombi* In three legs, in which contrast-encircled 'floating' thrombi were seen at the first postoperative phlebography, no contrast medium was visible in the vessel in question at the second examination The filling defect was in all these cases much larger than the thrombus demonstrated at the first phlebography

4 *Regression and progress of thrombi* In three legs, in which thrombi were present at the first examination, the second phlebography indicated that both regressive and progressive changes had taken place In two of these, the




Fig 9 a) and b) Thrombus (→) in the popliteal vein one month after prostatectomy c) and d) Total regression 6 months later

*Thrombi arising at a late stage after the operation* Three of the thrombosis cases in the material differed noticeably from the others and deserve a more detailed description In all three, routine postoperative phlebography 8, 9, and 16 days after the prostatectomy demonstrated apparently normal conditions One of these patients died 13 days after postoperative phlebography Necropsy revealed pulmonary embolism and widespread thrombosis of both femoral veins In this case the interval between operation and death was 21 days, and the connection between the operation and the thrombosis is thus obvious The second patient developed clinical signs of thrombosis 16 days after the first negative postoperative phlebography Further phlebography carried out immediately showed a thrombus in the popliteal vein, and another examination 5 months later indicated that no contrast medium passed through any of the deep leg veins. The interval between the intervention and the demonstration of thrombosis was just over one month and the connection between the operation and the thrombosis must therefore be assessed as probable The third patient had clinical signs of thrombosis a little over 4 months after a negative postoperative phlebography A second phlebographic examination at that time disclosed that no passage of contrast medium occurred through the deep leg veins. As the time interval was long it is not certain whether there was any connection between the operation and the thrombosis This possibility cannot however be excluded as the condition may have developed gradually over a long period without producing clinical signs




Fig 8 a) and b) Thrombus (→) in the popliteal vein 14 days after prostatectomy c) and d) Total regression 8 months later Valves are visible

as before the intervention (Figs 3, 4 and 10), and the other seven legs presented signs of residual changes of varying severity

'Floating' thrombi were observed in two legs before the operation in one instance it was a muscle vein thrombosis (Fig 12) and in the other a thrombophlebitis The postoperative venous status was unchanged sixteen and thirty one days respectively after the first examination in both these cases Extensive changes in the veins, with the typical post thrombotic appearances, were observed pre operatively in four legs, in all four the condition was unchanged postoperatively 4 to 23 days after the first examination A similar case was also observed in the group of postoperative phlebographies in which no pre operative examination was performed, the condition was still unchanged at further phlebography 6 months after the preceding one

In the remaining 77 legs, neither the pre operative nor the postoperative phlebography revealed any pathologic changes, both the contrast filling and the anatomic appearances of the veins were identically the same in both examinations

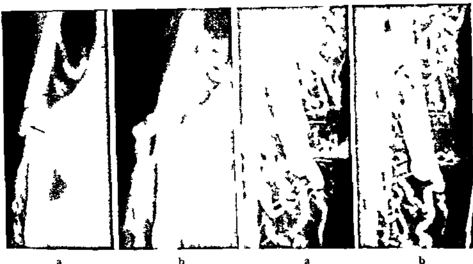



Fig 11 a) Thrombus (→) growing from the small saphenous vein into the popliteal vein 15 days after prostatectomy b) Total regression 6 weeks later

Fig 12 a) Muscle vein thrombosis (→) demonstrated at pre-operative phlebography b) Unchanged condition 30 days after prostatectomy

Our material differs considerably from most of the earlier thrombosis series studied by phlebography because in our patients postoperative phlebographies were carried out irrespective of whether they had had clinical signs of thrombosis or not In most of the previous investigations some form of clinical manifestation was the reason why phlebography was undertaken There are a few exceptions a series of fractures of the upper end of the femur, published by BORGSTROM et coll, a material of tibial fractures described by BERGVALL & HJELMSTEDT and a material of mixed traumas presented by FREEARK et coll The first of these series resembles the prostate material in our series as regards incidence and distribution of the condition

The *reliability of the phlebographic method in the diagnosis of thrombosis* has been much discussed in recent years It now seems to be generally recognized that the method irrespective of the technique employed, is always superior to the purely clinical means of examination The technique used in our cases has been proved by GREITZ to give the best conditions for producing homogeneous contrast filling of the venous system of the lower limbs BORGSTROM et coll have advanced arguments indicating that the method is reliable for demonstrating thrombosis.

Our group in which both pre and postoperative phlebographies were carried out, seems to corroborate the reliability of the method Had the contrast defects

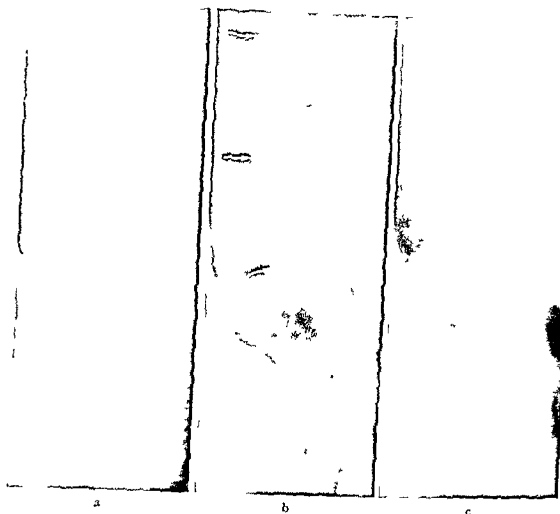



Fig 10 *Thrombus* (→) at junction between popliteal and femoral veins (b) 13 days after prostatectomy Two months later the thrombosed vein has resumed the same appearances (c) as at pre operative phlebography (a) Small saphenous vein widened at latest examination (c)

## Discussion

The material on which this investigation is based was selected All the patients had undergone prostatectomy This implies that the series is homogeneous as regards factors predisposing to thrombosis, and relatively homogeneous as to age distribution On the other hand, it does not throw much light on the manifestations and course of the thrombosing process in the wider sense Both the incidence and distribution of the disease might be different in a material of another composition, also the relation between clinical and phlebographically demonstrated thrombosis might not be the same as in other series

the other hand, from those described by NYLANDER (1968) and by HAEGER & NYLANDER (1967). In the latter report it was stated: 'acute thrombosis of the lower leg appears in the radiograms as nonvisualisation of all the deep veins of the leg under the crural fascia'. These authors mentioned the 'knot-hole phenomenon' and the 'deviated flow phenomenon' as other significant findings. NYLANDER believed that non-filling of the deep crural veins is as a rule a transient phenomenon caused by reactive edema, with a secondary increase in pressure which prevents passage through the deep veins. Non-filling of all the deep veins was observed only occasionally in our series, and occurred only in those cases in which the thrombi progressed over a long control period. In addition, there were a few cases with characteristic stationary post-thrombotic changes. The other features mentioned by NYLANDER were not observed in our cases. Dilatation of superficial veins was not seen in connection with the demonstration of a fresh thrombus but was observed in one or two cases after the thrombus had disappeared (Fig. 10).

The difference between the present observations and those of NYLANDER must be explained. NYLANDER described his thromboses as acute on the grounds that the phlebographies had been carried out as soon as clinical signs were noted. We used the term 'fresh thrombosis' because in most of our cases in which there were no clinical signs it could not be decided exactly when the thrombus had been formed. The fact that NYLANDER described two cases in which contrast-encircled thrombi were present a few days after a stage in which no filling of the deep venous stems was obtained lends support to the view that a time factor might possibly explain the discrepancy. That this difference could be the sole explanation of the phlebographic discrepancies seems unlikely however, since ZACHRISSON's material agrees closely with NYLANDER's series as regards indications but closely resembles our material in the phlebographic findings. Clinical signs in our series also led to the immediate performance of phlebographic examinations but the phenomena described by NYLANDER were not observed.

In all probability, NYLANDER's observations on the one hand and those of ZACHRISSON and the present authors on the other, reflect differences in the composition of the respective primary materials. It is not unlikely that prostatectomy is seldom complicated by thrombotic manifestations with such a relatively dramatic course as those in NYLANDER's series. Even in the early days, BAUER pointed out that thrombi encircled by contrast medium, such as those dominating the present material, do not as a rule produce clinical signs. It seems hardly likely that the highly 'thrombosis-minded' clinicians in our team would have consistently failed to notice signs of thrombosis if our cases had passed a stage with the phlebographic changes described by NYLANDER.

The literature contains only a few reports on the course of the thrombosing

which we interpreted as thrombi been artefacts due to technical factors in the examination then (1) contrast defects in large numbers would have been seen at the pre-operative examinations and (2) defects observed at the pre operative examinations would as a rule have disappeared or altered in appearance in the postoperative phlebograms This did not occur however The number of contrast defects in the pre operative films was small and much lower than in the post-operative examinations The defects seen before the operation and interpreted as thrombi or components in a post-thrombic condition, had exactly the same appearances at the postoperative examination carried out shortly afterwards These observations provide support for the view that the phlebographic technique used by us is a reliable aid in the diagnosis of venous thrombosis

The system with routine postoperative phlebographies does not however constitute a guarantee that a warning signal will be obtained before pulmonary embolism Our series afforded no definite indication regarding the best time for the performance of phlebography following operation to be sure of detecting a thrombus

As to *the incidence of thrombosis* it may be mentioned that the number of cases of thrombosis diagnosed by phlebography was nearly twice as high as the number disclosed by clinical signs This demonstrates quite plainly the superiority of phlebography as a diagnostic method A somewhat remarkable observation is that a certain element of clinical over-diagnosis seems to occur This was less apparent in our material than the clinical under-diagnosis HAEGER considered however that the risk of over diagnosis is considerable The clinical signs are so uncharacteristic and ambiguous that a certain degree of clinical over diagnosis is hardly surprising To this may be added the possibility that small thrombi, if not larger ones, that are attached insecurely to the vessel wall may break loose and move away out of range for a phlebographic diagnosis without necessarily producing any notable clinical manifestations

*The appearances and site of the thrombi* differed considerably in our cases from the conditions described in some other investigations Most of the thrombi in our series appeared, both in muscle veins and in deep venous stems, as filling defects encircled by contrast medium Thus, the appearances corresponded to the 'floating thrombi' described by BAUER (1940), LINDBOM (1952) and BORGSTROM et coll (1965) Most of the thrombi in our cases were located in muscle veins As regards appearance and localization, our series resembles those described by BORGSTROM et coll and by ZACHRISSON The selection of the material in our series differed from that in the two latter investigations It should be emphasized that ZACHRISSON always insisted upon having some form of clinical manifestation as an indication for phlebography The present material diverges radically, on

## Conclusions

Our investigations have provided further support for the view that the technique for ascending phlebography introduced by GREITZ is a reliable one in the diagnosis of thrombosis in the legs Postoperative phlebography has clearly demonstrated that the clinical diagnosis of thrombosis is unreliable Approximately half the number of cases with phlebographically demonstrated thrombi in our material had no clinical signs A certain amount of clinical over-diagnosis also occurred

A negative phlebogram constitutes no definite guarantee that the patient will not develop pulmonary embolism As the interval between the operation and the development of thrombosis seems to vary, it is difficult to give any indication as to the best time for *performing postoperative* phlebography

Thrombosis is diagnosed by phlebography in over one fifth of cases of pros- [illegible] uscle veins or deep venous stems of [illegible] lie in muscle veins or deep venous [illegible] thrombi' in phlebograms obtained shortly after the intervention, in other words, they appear as contrast encircled defects in the respective veins Non filling of all the deep veins was an uncommon finding in this material, it was observed only in those cases in which the thrombosis had progressed over a long observation period

An *acute floating thrombus" disappears without trace in over one third of* all cases It is not possible to say how rapidly this takes place but it occasionally occurred within 4 weeks and total regression within 3 months was often recorded

More than half the number of thrombi leave varying residual changes Small irregularities in the vein wall were common in the area where the thrombus had been situated Remnants of thrombi were sometimes seen, and in a few cases the thrombotic changes had progressed Regressive and progressive changes were sometimes present side by side in the same thrombosed region

A series of pre operative phlebographies indicated that it cannot be categorically concluded that all *postoperatively diagnosed thrombi* have arisen after the operation

*Pre-operative studies provided further support* for the view that thrombi may disappear altogether In this connection phlebograms obtained before the operation were valuable in the assessment of the normal anatomy of the veins

## SUMMARY

Postoperative thrombosis has been studied in 519 phlebograms *from 367 legs* in 187 cases following prostatectomy The diagnostic reliability of the clinical examination as compared

process It has long been known that certain types of thrombosis lead to post thrombotic conditions, especially in the form of extensive obliteration of deep venous stems, deformation of the walls of the veins and new formation of small tortuous vessels It is also known that pulmonary embolism not seldom occurs in cases in which the primary thrombosis has not given rise to symptoms As mentioned above, NYLANDER noted in a few cases a rapid development from a stage of non filling of the deep veins to a condition that could best be described as floating thrombi' HAEGER has maintained that a negative phlebogram long after a thrombosis has been suggested clinically is a sign that the suggestion was unfounded MAY & NISSL (1959) and BERGVALL & HJELMSTEDT (1968) studied the recanalizing course in deep thrombosis of the lower limbs after tibial fractures and reported that the process is very slow No other important systematic studies of the subsequent course of phlebographically verified thrombi seem to have been published

Our cases varied greatly as regards the continued course of the thrombosing process as far as this could be judged at repeat phlebography Total regression was not uncommon and was observed in over one third of the cases Although most of the cases in which thrombi were diagnosed received heparin, total regression was also observed in a few cases that had not received the drug In a further one fourth of the cases, there were no signs of persisting thrombosis but the walls in the previously thrombosed veins were irregular Thus, it seems as if approximately half the number of thrombi in a thrombosis series of the present type disappear so completely that a subsequent, isolated phlebographic examination affords no evidence of their having been present Regression occurred relatively rapidly in our cases, in half of them within 3 months

The other cases presented a wide diversity of changes, from small residual thrombi to thrombi that had progressed to conditions resembling earlier, well known post thrombotic states Regression and progression of thrombus masses were sometimes observed side by side in the same leg

This material includes a group of cases in which phlebographies were also carried out before the intervention It was naturally not our intention to investigate whether such examinations have any value as a routine Phlebographies are too time consuming examinations to be used routinely unless pressing medical reasons are at hand Nonetheless, it was considered that a series of pre operative phlebographies might give valuable information They established that it cannot be taken for granted that a thrombus demonstrated at postoperative phlebography really has arisen after the operation They also helped to establish that the concept of total regression of a thrombus is a reality since in a number of cases with definitely established thrombosis phlebographies carried out a considerable time after the condition was diagnosed revealed that the vascular anatomy had resumed its original pre operative appearances

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ZACHRISSON B (1968) Personal communication

with phlebography was investigated and the incidence, sites and phlebographic appearances of postoperative thrombosis are described *and compared with the findings of other investigators*

## ZUSAMMENFASSUNG

Das Auftreten der Postoperativen Thrombose in den Beinen nach Prostataentfernung wurde phlebographisch an 367 unteren Extremitaten in 187 Fallen studiert Die diagnostische Zuverlasslichkeit der klinischen im Vergleich zu der phlebographischen Untersuchung wurde uberpruft und das Vorkommen, der *Sitz und die phlebographischen Symptome der* Thrombose werden besprochen Die Resultate werden mit denen anderer Autoren verglichen

## RÉSUMÉ

Les auteurs ont etudie la thrombose post operatoire apres prostatectomie sur 519 phlebographies de 367 membres inferieure dans 187 cas Ils ont compare l exactitude du diagnostic clinique à la phlebographie et ils decrivent la frequence, le siege et les images phlebographiques *de la thrombose post-operatoire et comparent leurs résultats* avec ceux d autres auteurs

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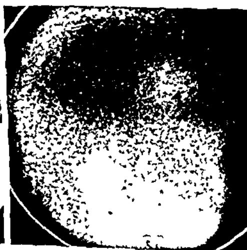


Fig 1 Lateral scintigram of left hemisphere Multiple metastases (bronchogenic carci noma)

1967, Loken, Telander & Salmon 1965, Loken, Telander & Laxdal 1966, Telander & Loken 1967)

The expected differences might mainly be attributed to the different collimation The gamma camera with its non-focussing collimator would probably give a better representation of superficial tumours, metastases and infarction, and at the same time a better representation of superficial extracerebral structures





a b

Fig 2 A p (a) and right lateral (b) scintigrams Glioblastoma of corpus callosum.

FROM THE DEPARTMENTS OF NEUROLOGY AND NEUROSURGERY AND THE RADIO PHYSICAL LABORATORY, ODENSE SYGEHUS, DENMARK

# SCINTILLATION CAMERA AND RECTILINEAR SCANNER FOR DETECTION OF SPACE OCCUPYING INTRACRANIAL LESIONS

by

MOGENS PEDERSEN and JENS HAASE

Most authors have found no substantial difference in the diagnostic accuracy between the two most commonly used isotopes for brain scintillography, $^{99}Tc^{m}$ and $^{197}Hg$ chlormerodrin while in practice the prevailing circumstances may indicate the technetium isotope to be the one of choice The short half life (6 hours) allows a high dose to be given without exceeding the permissible limits of radiation load This high permissible dose ensures good counting statistics and shorter examination procedures

The gamma scintillation camera (ANGER 1963) has found increasing application since 1965 in cerebral as well as in other scintillographic procedures The disintegrations in the whole organ under study are recorded in one field of vision in contrast to the rectilinear scanning system which produces successive point by point recording of the disintegrations In large organs like the brain this latter method is rather time consuming

Only few studies have been undertaken to compare the clinical results of the two methods those available being mostly phantom investigations (ANGER et coll

Submitted for publication 14 November 1969

a b

*Fig 4 A p (a) and right lateral (b) scintigrams Arteriovenous malformation in right hemisphere*

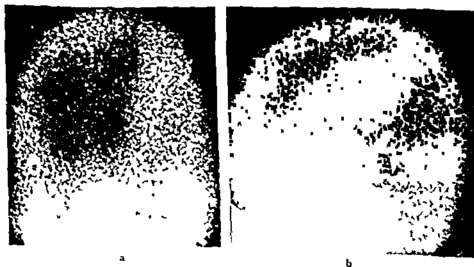



Fig 5 A p (a) and left lateral (b) scintigrams An 8 day old infarction in the left hemisphere.



Fig 3 Lateral scintigram of right hemisphere Temporal lobe abscess

such as the temporal muscle and isotope concentrating processes in the cranial wall The rectilinear scanner, on the other hand, which is equipped with a focussing collimator, would possess an advantage in that tumours in the focal plane of the collimator can be demonstrated, while at the same time a smoothing out effect on more superficial isotope concentrations would be produced

All the brain scintillographies in our department from September 1968 to June 1969 were made with both the rectilinear scanner and the gamma camera with a view to investigate whether the fast working gamma camera yielded the same diagnostic accuracy as the rectilinear scanner

*Method* Technetium 99m pertechnetate ($^{99}Tc^{m}$) from a Philips/Duphar generator (molybdenum 99m ammonium molybdate absorbed in aluminium oxide) in a dose of 100 to 150 $\mu$Ci/kg, 8 to 15 mCi per study, was given intravenously Rectilinear scanning was performed first and was started 20 minutes after the injection of the isotope Depending on the duration of this examination, the gamma camera investigation followed 60 to 80 minutes after the injection No potassium perchlorate or atropine was used

The rectilinear scanner was a Picker Magna V, with a 5″ NaI crystal and a 5″ 85 hole focussing collimator, Picker 2011, collecting 8 000 to 12 000 counts per minute with a scanning speed of 100 to 110 cm/minute, background subtraction 10 to 25 %, total time per study 40 to 60 minutes The scintigrams are presented in color script and photographic film in the magnitude 1 1

The gamma camera was a Nuclear Chicago Pho/Gamma III equipped with a 11 5″ × 0 5″ NaI crystal and a 4 000 hole non focussing collimator, collecting

**Table 2**

*Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with space-occupying cerebrovascular episodes*

| Nature of process | Days after episode | Number | Verified | Gamma camera ++ | Gamma camera + | Gamma camera 0 | Scanner ++ | Scanner + | Scanner 0 |
|---|---|---|---|---|---|---|---|---|---|
| Infarction | 0— 3 | 4 | 2 | 1 | 0 | 3 | 1 | 0 | 3 |
| | 4— 7 | 9 | 9 | 3 | 1 | 5 | 5 | 2 | 2 |
| | 8—14 | 7 | 4 | 5 | 1 | 1 | 4 | 1 | 2 |
| | 15—21 | 3 | 3 | 2 | 1 | 0 | 2 | 1 | 0 |
| | > 22 | 6 | 6 | 4 | 1 | 1 | 3 | 1 | 2 |
| Hematoma | | 3 | 3 | 1 | 0 | 2 | 1 | 0 | 2 |
| Total Number | | 32 | 27 | 16 | 4 | 12 | 16 | 5 | 11 |
| Total Per cent | | 100 | 84 | 63 | | 37 | 66 | | 33 |

**Table 3**

*Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with non malignant space occupying lesions*

| Nature of process | Number | Verified | Gamma camera ++ | Gamma camera + | Gamma camera 0 | Scanner ++ | Scanner + | Scanner 0 |
|---|---|---|---|---|---|---|---|---|
| Encephalitis | 10 | 9 | 5 | 1 | 4 | 5 | 1 | 4 |
| Meningocerebral cicatrix | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Hygroma | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Arachnoid cyst | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 1 |
| Temporal lobe cyst | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Temporal lobe abscess | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Total Number | 16 | 15 | 8 | 1 | 7 | 8 | 2 | 6 |
| Total Per cent | 100 | 94 | 56 | | 44 | 62 | | 38 |

## Results

Intracranial space-occupying lesions were detected in 105 (49 %) of the 213 patients forming the series Space occupying lesions include primary and secondary neoplasms, infarctions, encephalitis and intra- and extracerebral hematomas The final diagnosis was made by operation, autopsy or neuroradiologic studies in 92 patients of the series and in a further 13 the diagnosis was established by the clinical course of the disease Both supra- and infratentorial tumours were present in one patient

**Table 1**

*Scintillographic results obtained with gamma camera and rectilinear scanner in supra and infratentorial tumours*

| Nature of process | Number | Verified | Gamma camera | | | Scanner | | |
|---|---|---|---|---|---|---|---|---|
| | | | ++ | + | 0 | ++ | + | 0 |
| *Supratentorial* | | | | | | | | |
| Glioma benign | 7 | 7 | 3 | 0 | 4 | 3 | 1 | 3 |
| Glioma malignant | 4 | 4 | 3 | 0 | 1 | 3 | 0 | 1 |
| Glioblastoma | 13 | 13 | 13 | 0 | 0 | 13 | 0 | 0 |
| Meningioma | 9 | 9 | 8 | 0 | 1 | 7 | 1 | 1 |
| Metastases | 14 | 8 | 13 | 1 | 0 | 14 | 0 | 0 |
| Arteriovenous malformation | 3 | 3 | 3 | 0 | 0 | 3 | 0 | 0 |
| Other tumours | 3 | 3 | 2 | 0 | 1 | 0 | 1 | 2 |
| Total Number | 53 | 47 | 45 | 1 | 7 | 43 | 3 | 7 |
| Total Per cent | 100 | 89 | 87 | | 13 | 87 | | 13 |
| *Infratentorial* | | | | | | | | |
| Acoustic neurinoma | 2 | 2 | 1 | 0 | 1 | 1 | 0 | 1 |
| Metastases | 2 | 1 | 2 | 0 | 0 | 2 | 0 | 0 |
| Pontine glioma | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Total Number | 5 | 4 | 3 | 0 | 2 | 3 | 0 | 2 |
| Total Per cent | 100 | 80 | 60 | | 40 | 60 | | 40 |

100 000 counts per minute up to a total of 400 000 to 500 000 counts The studies were performed using three or four projections, which required a total of 15 to 20 minutes per study The results are presented in scintigrams of different intensity on 7 cm × 9 cm polaroid film

The examinations were performed by well-trained laboratory workers, as routine work under definite rules The scintigrams were assessed by the authors together, without knowledge of the diagnosis or the clinical conditions of the patient

Scintigrams with pathologic activity of an intensity equal to or greater than the activity of the frontal cranial wall were classed ++ positive, those of intensity less than that of the cranial wall but greater than the activity normally seen were classed + positive, while those with a low homogeneous activity over the cerebral hemispheres and the posterior fossa were recorded as negative

The quality of the scintigrams was also judged as regards incorrect adjustment of instruments, distortion of projections and movement

**Table 2**

*Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with space-occupying cerebrovascular episodes*

| Nature of process | Days after episode | Number | Verified | Gamma camera ++ | Gamma camera + | Gamma camera 0 | Scanner ++ | Scanner + | Scanner 0 |
|---|---|---|---|---|---|---|---|---|---|
| Infarction | 0—3 | 4 | 2 | 1 | 0 | 3 | 1 | 0 | 3 |
| | 4—7 | 9 | 9 | 3 | 1 | 5 | 5 | 2 | 2 |
| | 8—14 | 7 | 4 | 5 | 1 | 1 | 4 | 1 | 2 |
| | 15—21 | 3 | 3 | 2 | 1 | 0 | 2 | 1 | 0 |
| | > 22 | 6 | 6 | 4 | 1 | 1 | 3 | 1 | 2 |
| Hematoma | | 3 | 3 | 1 | 0 | 2 | 1 | 0 | 2 |
| Total Number | | 32 | 27 | 16 | 4 | 12 | 16 | 5 | 11 |
| Total Per cent | | 100 | 84 | 63 | | 37 | 66 | | 33 |

**Table 3**

*Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with non malignant space-occupying lesions*

| Nature of process | Number | Verified | Gamma camera ++ | Gamma camera + | Gamma camera 0 | Scanner ++ | Scanner + | Scanner 0 |
|---|---|---|---|---|---|---|---|---|
| Encephalitis | 10 | 9 | 5 | 1 | 4 | 5 | 1 | 4 |
| Meningocerebral cicatrix | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Hygroma | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Arachnoid cyst | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 1 |
| Temporal lobe cyst | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Temporal lobe abscess | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Total Number | 16 | 15 | 8 | 1 | 7 | 8 | 2 | 6 |
| Total Per cent | 100 | 94 | 56 | | 44 | 62 | | 38 |

## Results

Intracranial space-occupying lesions were detected in 105 (49 %) of the 213 patients forming the series. Space-occupying lesions include primary and secondary neoplasms, infarctions, encephalitis and intra- and extracerebral hematomas. The final diagnosis was made by operation, autopsy or neuroradiologic studies in 92 patients of the series and in a further 13 the diagnosis was established by the clinical course of the disease. Both supra- and infratentorial tumours were present in one patient.

### Table 4

*Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with other intracranial lesions than space occupying*

| Nature of process | Number | Verified | Gamma camera | | | Scanner | | |
|---|---|---|---|---|---|---|---|---|
| | | | ++ | + | 0 | ++ | + | 0 |
| Arteriosclerotic encephalopathy | 24 | 22 | 2 | 0 | 22 | 2 | 2 | 20 |
| Hypertensive encephalopathy | 4 | 2 | 0 | 2 | 2 | 0 | 2 | 2 |
| Transistory cerebral ischemia | 7 | 4 | 0 | 0 | 7 | 0 | 0 | 7 |
| Non tumorous epileptic disorders | 26 | 24 | 0 | 2 | 24 | 1 | 2 | 23 |
| Migraine | 14 | 5 | 1 | 1 | 12 | 0 | 1 | 13 |
| Paralysis agitans | 5 | 2 | 0 | 0 | 5 | 0 | 0 | 5 |
| Neurosis | 7 | 4 | 1 | 1 | 5 | 0 | 0 | 7 |
| Others | 21 | 11 | 2 | 1 | 18 | 2 | 4 | 15 |
| Total Number | 108 | 74 | 6 | 7 | 95 | 5 | 11 | 92 |
| Total Per cent | 100 | 69 | 12 | | 88 | 15 | | 85 |

### Table 5

*Positive scintigrams obtained in a group of patients with other intracranial lesions than space occupying*

| Nature of process | Gamma camera | | Scanner | |
|---|---|---|---|---|
| | ++ | + | ++ | + |
| Choroid plexus | 2 | 2 | 2 | 3 |
| Cranial wall metastases | 2 | 0 | 2 | 0 |
| Soft tissue trauma | 1 | 0 | 0 | 0 |
| Mucocele in frontal sinus | 0 | 1 | 0 | 1 |
| Sequelae from craniotomy | 0 | 0 | 0 | 1 |
| 'False positive' | 1 | 4 | 1 | 6 |
| Total | 6 | 7 | 5 | 11 |

For the whole group of space-occupying lesions (Tables 1, 2 and 3) the positive scintigrams were 78 (73.5 %) and 75 (70.5 %) respectively from the gamma camera and the scanner while in the group of supra- and infratentorial tumours (Table 1) 80 % positive scintigrams were obtained, this group includes tumours of all grades of malignancy.

As regards the results of scintillography in supratentorial tumours (Table 1) it may be observed that a small flat suprasellar meningioma escaped detection both by the gamma camera and the scanner but the high diagnostic accuracy for glioblastomas, meningiomas and metastases is notable.

Table 6

*Analysis of the technical quality of scintigrams obtained with respectively gamma camera and rectilinear scanner*

| Characterization | | Gamma camera | Scanner |
|---|---|---|---|
| Unsatisfactory | | 0 | 8 |
| Movement | | 3 | 22 |
| Oblique | | 3 | 9 |
| Wrong projection | | 1 | 2 |
| Instrumentation | | 0 | 6 |
| Total | Unsatisfactory | 0 (0 %) | 8 (4 %) |
| | Just acceptable | 7 (3 %) | 39 (18 %) |

Table 7

*Comparison of the qualities of the positive (++) scintigrams obtained with the gamma camera as well as the rectilinear scanner*

| Nature of process | | Number | Camera better | Scanner better | Equally good |
|---|---|---|---|---|---|
| Glioma benign | | 3 | 2 | 0 | 1 |
| Glioma malignant | | 3 | 1 | 1 | 1 |
| Glioblastoma | | 13 | 6 | 1 | 6 |
| Meningioma | | 7 | 1 | 1 | 5 |
| Metastases | | 13 | 3 | 1 | 9 |
| Arteriovenous malformation | | 3 | 2 | 0 | 1 |
| Infarction | | 12 | 5 | 1 | 6 |
| Intracerebral hematoma | | 1 | 0 | 0 | 1 |
| Encephalitis | | 5 | 3 | 2 | 0 |
| Other supratentorial space occupying lesions | | 4 | 1 | 1 | 2 |
| Infratentorial tumours | | 3 | 0 | 1 | 2 |
| Total | Number | 67 | 24 | 9 | 34 |
| | Per cent | 100 | 36 | 13 | 51 |

Scintillographic demonstration of tumours of the posterior fossa is known to be difficult, especially with $^{99}Tc^{m}$ because of the high concentration of the isotope in the tissues overlying this area. The present series of patients included only five with such tumours, two with metastases and two with an acoustic neurinoma. The pontine glioma and one of the neurinomas were not diagnosed by the gamma camera nor by the scanner.

Cerebrovascular episodes are according to most authors (GLASGOW et coll

1967, MOLINARI et coll 1967) best demonstrated by scintillography 7 to 14 days following their occurrence This was only partly confirmed by the present investigation (Table 2). The discrepancy in the results of scintillography by the two methods obtained from 4 to 7 days after a cerebrovascular episode, where the scanner seemed to give the best results, may be explained by the earlier mentioned assumption that the gamma camera over-emphasizes superficial activity and consequently hides underlying pathologic activity of low intensity

Among the non-malignant, space-occupying lesions the group 'encephalitis' deserves special attention (Table 3) Marked scintillographic abnormalities, comparable to those seen in malignant tumours, were present in five out of ten patients and in a further patient less prominent but still abnormal changes were recorded A large arachnoid cyst in the fissura Sylvii was faintly demonstrated by the scanner but was missed by the gamma camera

In the inhomogeneous group of patients without space-occupying lesions (Table 4) 74 diagnoses out of 108 (67 %) were verified by operation, autopsy or neuroradiologic studies, in this group 13 and 16 abnormal scintigrams were obtained respectively by the gamma camera and the scanner Five of these were due to two metastases to the cranial wall, one traumatic lesion, one mucocele and one from postoperative sequelae, while four and five, respectively, on revision turned out to be due to a misinterpreted plexus chorioideus This left five and seven, respectively, as false positives (Table 5)

The technical qualities of the scintigrams are compared in Table 6 The gamma camera scintigrams were never without value while rectilinear scanning in eight instances gave completely unsatisfactory results If the patient moves this is a difficult problem in rectilinear scanning but hardly any problem with the faster gamma camera

Sixty-seven scintigrams which with both examination methods were ++ positive formed the basis on which to select the better method of demonstrating a lesion (Table 7) The representation was equally good in half the number of patients while the gamma camera provided the better demarcation of the lesion in 36 % of the patients

## Discussion and Conclusion

The results usually reported in cerebral scintillography using $^{99}Tc^{m}$ appear to be more or less confirmed Apart from the apparently better demonstration of infarction by rectilinear scanning in the period 4 to 7 days after a cerebral episode, no essential differences in diagnostic accuracy were observed between the two methods In no instance did the scanner reveal a neoplasm that was not equally well, or even better, demonstrated by the gamma camera We feel that

the gamma camera often provides a sharper representation of pathologic changes, especially in cases of infarction Furthermore, although not definitely confirmed in the present series of patients, the camera appears to be more satisfactory for the posterior fossa than the rectilinear scanning system with $^{99}Tc^{m}$

The practical advantages of the gamma camera are obvious Much shorter time is required for each examination, an important point in view of the fact that the patients are often seriously ill and uncooperative Gamma camera scintillography appears to be little susceptible to movement The mini size of the gamma camera films at first sight appears to constitute a disadvantage and a solution to this problem could be to enlarge the scintigrams In our opinion a better method is however to use the gamma camera study as a screening procedure, which we have done since the termination of the present investigation After screening, the lesion is scanned conventionally from the relevant side, using a suitable projection, if possible with the focal plane of the detector at the level of the pathologic process. The conditions for the production of a full size scintigram then become ideal

## SUMMARY

Two hundred and thirteen patients were investigated with a gamma camera and a rectilinear scanner for tumours and other intracranial conditions No essential differences between the two methods as regards diagnostic accuracy were apparent although the gamma camera appeared to possess considerable practical advantages

## ZUSAMMENFASSUNG

Zweihundertdreizehn Patienten mit Gehirntumoren und anderen intrakraniellen Lasionen wurden mit Gammakamera und geradliniger Szintigraphie untersucht. Keine wichtigen Unterschiede wurden hinsichtlich der diagnostischen Zuverlasslichkeit zwischen den beiden Methoden beobachtet die Gammakamera erwies sich jedoch als praktischer im Gebrauch

## RÉSUMÉ

Deux cent treize malades atteints de tumeurs ou d autres affections intra-craniennes ont ete examines au moyen d une gamma-camera et d un scintigraphe rectiligne Les auteurs n ont pas constate de differences essentielles entre ces deux methodes en ce qui concerne la precision du diagnostic mais la gamma-caméra présente des avantages pratiques considerables.

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# ROENTGEN EXAMINATION OF THE FACIAL CANAL

by

S Brunner and Chr Brahe Pedersen

Tomography of the temporal bone usually proves of considerable value in the investigation of facial palsy The method enables the detail of the bone, including its osseous walls, to be examined Advances in otosurgery have provided a new approach for treatment of facial palsy, and the exact localization of the site of a pathologic process in the temporal bone has become an essential pre-operation requisite

*Anatomy* The facial, or seventh cranial, nerve passes through a long osseous canal, the facial canal, shortly after leaving the *pons* The facial canal, 5 cm in length is divided into three parts (Fig 1) The *first* part stretches from the internal auditory meatus to the geniculate ganglion, it is about 1 5 cm long and most of the way lies just above the accompanying acoustic nerve The facial nerve performs a 100 degree bend in the medial wall of the tympanic cavity above the cochlea and vestibular window and below the lateral semicircular canal a second bend occurs at the pyramidal eminence The third part of the facial canal runs inferovertically and is about 1 5 cm in length The canal then opens out at the base of the skull into the stylomastoid foramen The course now described is the normal one

Submitted for publication 9 December 1969




Fig 1 Anatomy of the facial canal modified after SHAMBAUGH Geniculate ganglion and first bend (1) second bend (2), third part of canal (3), stylomastoid foramen (4), vestibular window (5), semicircular canal (6) cochlea (7), carotid canal (8), incus (I), and malleus (M)

Atypical courses of the facial nerve have sometimes been described (KETTEL 1963) and are of considerable surgical importance The nerve in its intraosseous course sends several fibres to the salivary and lacrimal glands and to the taste buds, and innervates the stapedius muscle Examinations of these nerve functions make a topographic diagnosis in lesions of the facial nerve possible (SHAMBAUGH 1967) The nerve is abundantly supplied with blood, each part from at least two sources The canal is so wide that the nerve only occupies 50 to 70 per cent of its volume

*Tomographic representation* The facial canal may be demonstrated in its full length by tomography of the temporal bone with 1 mm between the cuts The best projections for a correct assessment of the canal are a p and lateral projections, supplemented by a half-axial projection (BRUNNER et coll 1961, VALVASSORI 1963)

To provide an accurate concept of the roentgen anatomy, a wire was placed in the facial canal of a phantom The first and second horizontal parts of the canal are depicted in Fig 2, representing an a p tomographic cut in the cochlear plane, in which the facial canal appears as two foramina just above the cochlea The




Fig 2 A p tomography of a phantom at level of cochlea Facial canal appears as two foramina just above the coch lea (3)




Fig 3 A p tomography 2 mm more posteriorly than in fig 2 Second bend (1), mastoid part (2), and petrous part (3), of the facial canal




Fig 4 Lateral tomography of a phantom at level of the facial canal Second bend (1), and vertical or mastoid parts (2), of the canal

medial of these is the end of the first part of the facial canal which contains the geniculate ganglion and is often a little wider The lateral 'hole' constitutes the beginning of the second part of the facial canal

A cut a few millimeters more posteriorly (Fig 3) demonstrates the position of the facial canal in relation to the vestibular window, the canal being situated just above the latter and just below the lateral semicircular canal A lateral tomogram demonstrates the anatomical conditions of the canal placed deep in the mastoid process as it continues its vertical course (Fig 4)

The normal roentgenologic appearances are presented in Fig 5, which is an a p tomographic cut in the cochlear plane A spiral shaped cochlea lies in the centre, with the canal represented by two 'holes' proximal to the cochlea The lateral of these, containing the second part of the canal, is often represented more as a pit than a hole The second bend and the vertical course of the canal to the stylomastoid foramen is usually well demonstrated by lateral tomography (BRUNNER 1969) (Fig 6)

The *causes of facial palsy* may be divided into (1) diseases of the central nervous system, (2) local conditions, (3) systemic diseases, with or without peripheral neuropathy, and (4) unknown etiology Roentgenologic changes in the facial canal, as in other situations, may be caused by trauma, inflammation, or neoplasms

*Fractures of the temporal bone* may be divided into longitudinal and transverse, a combination seldom occurs

Longitudinal fractures are the more frequent ones The symptoms and signs are bleeding from the ear, hematotympanum and rupture of the tympanic







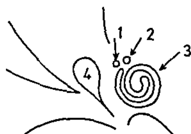



Fig 5 Ap tomography at level of cochlea of a normal right ear The lateral meatus is produced by the tympanic segment of the canal (1) the medial hole is larger because it contains the geniculate ganglion and the pet*rous segment of the facial nerve* (2) cochlea (3) malleus (4)

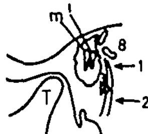



Fig 6 Lateral tomography at the level of the facial canal of a normal left ear Second bend of facial canal (1) mastoid course of facial canal (2) malleus (m) incus (i) and the tempero*mandibular joint* (T)

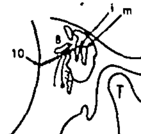



Fig 7 Lateral tomography in a female with right facial palsy after a traffic accident 2 weeks earlier Fracture (arrows 10) involves the facial canal near the second bend in its mastoid *part* (3) *incus* (i) *malleus* (m) and temperomandibu*lar joint* (T)

membrane (PETERSEN 1961) The facial nerve is involved in about 25 % of cases, the vertical part of the canal and the region of the second bend are most *often affected (Fig 7) Facial palsy is usually of the delayed type, presumably due to swelling, bleeding or ischemia Treated conservatively the prognosis is fair*

In transverse fractures, hematotympanum also occurs, but bleeding from the ear and rupture of the eardrum are unusual Transverse fractures are in 50 % of cases followed by facial palsy The fractures often involve the cochlea or the capsule of the labyrinth, causing total deafness in the same way as a fracture of the first part of the facial canal because of its site close to the acoustic nerve The palsy is of the immediate type and the prospects of spontaneous remission are poor

The cessation of facial function in direct relationship to the trauma or the appearance of facial palsy within a few days are clinically important In the first




Fig 8 A p tomography in a female aged 66 with right chronic otitis media for many years and right peripheral facial palsy for 3 months Destruction of the spur' of the lateral wall of attic (1) and handle of the malleus as well as of the medial wall of the attic around the facial canal (2) Squamous cell carcinoma




Fig 9 Lateral tomography in a female aged 61 who 2 years earlier was operated upon for a left parotid tumour, left peripheral facial palsy for 6 weeks Destruction of the mastoid extending into and around the third part of facial canal (arrow) malleus (m) incus (i) the facial canal (4)




Fig 10 A p tomography in the cochlear plane of male aged 45, with left chronic otitis media complicated by cholesteatoma left peripheral facial palsy for one week De struction of the lateral wall of the attic and the spur' (2) as well as of the medial wall of the attic containing the sec ond part of the facial canal (1), the cochlea (4)

case operation is definitely indicated while in the second the prognosis is relatively good without treatment It may prove difficult to decide whether the facial palsy in an unconscious patient is acute or delayed

Another kind of lesion of the facial canal is one produced by the iatrogenetic factor of ear operations According to KOERNER, an earlier investigation has revealed lesions of the facial nerve in 3 7 % of all otosurgical operations With improved operation techniques, the incidence of facial complications in primarily operated ears is in these days probably about 1 %, while facial lesions may occur in about 10 % of re operations

*Tumours* The facial nerve may be affected by benign or malignant growths The benign tumours consist mostly of neurinomas, these usually arise from the acoustic nerve — which in the first part of the facial canal is closely related to the facial nerve — and involve the facial nerve indirectly (VALVASSORI 1969)

Primary malignant neoplasms are generally represented by squamous cell



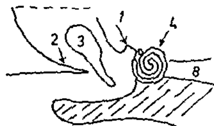




Fig. 11. A.p. tomography in the cochlear plane of male, aged 49, with right chronic otitis media of 6 years and facial palsy of 5 days duration. Destruction around the second part of facial canal (1) and blurring of the attic. Normal lateral wall and 'spur' (2), malleus (3) and cochlea (4).

carcinoma, seldom by sarcoma, which arise in the external auditory canal or in the middle ear, erode the facial canal and affect the facial nerve (Fig. 8). Secondary growths — such as from parotid tumours (Fig. 9) or rhinopharynx carcinoma spreading into the surrounding tissue — may likewise result in destruction of the facial nerve. Metastases from primary carcinoma of the mammae or lungs may, if located in the temporal bone, involve the nerve. Metastases from the gastro-intestinal tract are of course rarely encountered in this region.

*Infection.* Meningitis, tuberculosis, syphilis, herpes zoster and infectious mononucleosis, and so forth, may produce facial paralysis. Cessation of function of the facial nerve most frequently occurs after chronic otitis media or cholesteatomatous otitis. Acute otitis media may also result in facial palsy produced by reactive edema. It is important in chronic otitis media to determine whether a cholesteatoma is present or not, the typical roentgenologic characteristics being destruction of the 'spur', ossicles and the smooth-walled cavity of the antrum (BRUNNER 1969). Continuation of the growth may result in a destruction of the osseous wall of the facial canal, followed by palsy caused by pressure or infection of the nerve (Fig. 10). Destruction of the osseous walls of the facial canal also occurs in chronic otitis media though usually only of the medial wall of the tympanic cavity, the 'spur' and the ossicle remaining intact (Fig. 11).

## Discussion

Facial palsy is not uncommon. An etiologic explanation of its origin must always be sought in every case, as it is upon this that the course depends. It is always important to determine whether the paralysis has been caused by a reactive

nerve block or if the nerve fibres have degenerated, which means that confirmation is dependent on the regeneration of the latter A close clinical examination may indicate a prognosis of spontaneous remission but this alone is not enough for establishing whether the case will improve or not The nerve excitability test, in which the smallest electric current necessary for making a muscle contract is measured, is of considerable value, particularly when considering an operation (JONGKEES 1969)

Tomography of the facial canal may prove another valuable help in evaluating the chances of spontaneous healing by suggesting the basic disease leading to the facial paralysis

JONGKEES (1965) mentioned that the use of tomography made it possible to demonstrate the exact position of a fracture in 21 out of 25 cases. Tomography, together with clinical considerations, may indicate an operation of decompression

Tomography will enable the extension, localization and complication of a cholesteatoma of the middle ear to be assessed This may sometimes make it possible to determine whether the facial palsy has been brought on by a chronic middle ear operation with destruction of the facial canal, or has just been caused by reactive edema In the first instance the pressure on the canal will be relieved by the removal of granulations by open operation

Normal tomography in a patient with facial palsy must obviously exclude a number of possible causes and will in itself prove a valuable aid

## Conclusion

Tomography of the facial canal is a valuable supplement to other examinations in the investigation of facial palsy Traumatic changes, tumours or inflammatory changes in or about the canal will often be accurately diagnosed and the method must be regarded as secondary only to the clinical evaluation

## SUMMARY

The anatomy of the facial canal is described in some detail and the role of tomography of the temporal bone in the diagnosis of inflammation fractures and neoplasms as causes of facial palsy is discussed It is emphasized that tomography is an essential examination in this not uncommon condition

## ZUSAMMENFASSUNG

Die Anatomie des Gesichtskanals wird detailliert beschrieben [illegible] Wert der Tomo-
[illegible]n und Neoplas-
[illegible]ss Tomographie

## RÉSUMÉ

Les auteurs decrivent de façon assez detaillee l'anatomie du canal facial et examinent le rôle de la tomographie du rocher dans le diagnostic de la cause inflammatoire trauma tique ou neoplasique de la paralysie faciale Ils insistent sur l interet essentiel de la tomo graphie dans cette affection qui n est pas exceptionnelle


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# CANNULA FOR INJECTION OF CONTRAST MEDIUM IN CEREBRAL ANGIOGRAPHY

by

GUNNAR WESTBERG

Cerebral angiography is now often performed by means of a catheter passed through the femoral artery The need for angiographic examinations by direct puncture of the carotid artery will however always exist

Direct puncture with a needle and the Seldinger method of an indwelling catheter are both connected with certain disadvantages Plastic catheters threaded on a needle have long been in use for puncture of the liver and spleen SOILA (1963) described a similar method for introduction of a soft cannula into the carotid artery by direct percutaneous puncture' This was a step *in the right* direction but it would appear that the Soila catheter of teflon is too stiff and likely to cause intimal damage as it is pushed up through the vascular lumen SOILA furthermore, recommended the use of an inner *needle, 1* cm longer than the catheter threaded on it This however tends to increase the difficulty of introduction rather than otherwise, as the needle has to be passed a considerable distance into the artery before the catheter can be pushed off the needle into the vessel

There is thus a need for an improved instrument for direct puncture of the

Submitted for publication 31 January 1970

## RÉSUMÉ

Les auteurs décrivent de façon assez detaillee l'anatomie du canal facial et examinent le rôle de la tomographie du rocher dans le diagnostic de la cause inflammatoire, traumatique ou neoplasique de la paralysie faciale Ils insistent sur l'interet essentiel de la tomographie dans cette affection qui n'est pas exceptionnelle

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cannula is softer than teflon although sufficiently stiff to enable it to be passed up into a blood vessel, without the aid of a guide, if the angle of puncture is not too steep, an angle of 45°, or a little less, is suitable The needle tip has a bevel of 30° The outer cannula has an external diameter of 1 60 mm and an internal diameter of 1 14 mm The stylet has of an inner diameter of 0 7 mm and its length is 10 cm The tip of the outer cannula reaches to the eye of the stylet (Fig 2)

Prior to puncture, a hole should be made in the skin with a larger needle or a scalpel If this is not done, there is a risk that the catheter tip may be deformed as it passes through more or less tough skin After the artery has been punctured, the outer cannula is advanced over the stylet and pushed into the blood vessel for a distance of one or two centimeters before the stylet is withdrawn This ensures that the cannula does not slip out (Fig 3) If there is any uncertainty regarding the position of the needle, a check can be made by injecting contrast medium through the stylet before the outer cannula is removed The stylet having been withdrawn, it should not be re inserted while the outer cannula is still in position, as there then would be a considerable risk that it might perforate the cannula The resistance to injection is low in the outer cannula, much less than in a metal needle of the same caliber

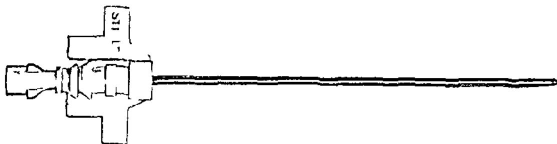
The instrumentarium forms part of a series that can be built up with the aid of Luer couplings and includes units with stopcocks, side holes, and other elements A middle piece consists of transparent tubing that can be compressed with artery forceps or other types of clamp A special tap, if considered necessary, can readily be fitted to the middle piece

This system has been in use for over a year and has proved highly advantageous The value of having a soft plastic tube in the artery instead of a metal needle is obvious, especially when the patient is likely to be restless or when alterations in the positioning of the head for different projections may endanger the correct position of the needle The equipment has also proved useful for retrograde injection of contrast medium into the brachial artery for vertebral angiography

The equipment is supplied in an expendable pack by AB Stille Werner, Stockholm under the name Stille Contrast Injection Cannula

## SUMMARY

Equipment for direct puncture of the carotid artery, consisting of a modification of the Stille infusion cannula is described The cannula has been on trial for more than a year and its value has been proved



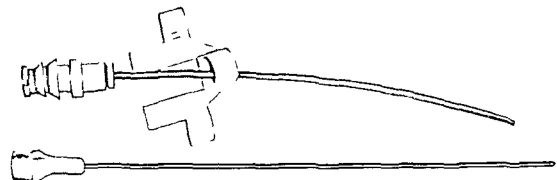
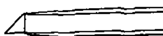


Fig 1 The assembled puncture instrument is shown at the top and the separate parts below

Fig 2 The tip of the outer cannula reaches to the eye of the stylet



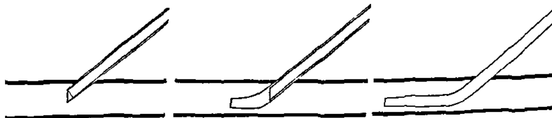


Fig 3 The outer cannula is introduced a certain distance before removal of the stylet

carotid artery The Stille infusion cannula, which has been on the market for some time, has been modified and appears to offer many advantages (Fig 1)

The instrumentarium consists of an inner stylet of flexible steel wire and an outer cannula of polythene, *both in a sterile pack* The wire stylet, before its removal from the pack, can without difficulty be shaped as desired The outer

FROM THE ROENTGEN DEPARTMENT (DIRECTOR OVE MATTSSON), ERSTA SJUKHUS, STOCKHOLM, SWEDEN

# A SAFER ENEMA NOZZLE

by

OVE MATTSSON

The examination of the colon by means of a barium enema is a frequent roentgen procedure, generally considered to be without risk. The anatomic deviation of the rectum dorsally against the sacrum favours however lesions in the ventral rectal wall. If the tip of the nozzle of the enema tube is pressed tightly against the rectal wall, local pressure increase may result (Fig. 1, an arrow indicates the opening in the tip). Perforation of the mucous membrane will then make injection of the contrast medium into the soft tissues a possibility, with dire results.

Several cases of serious injury to the rectum in connection with enemas are reported in the literature. In 1937 GALBRAITH described trauma caused by the use of a rigid enema nozzle. BALLON & GOLDBLOM (1941) reported the effects caused by incorrectly administered enemas. BOMAN et coll. (1952) described massive fatal embolism during a barium enema examination probably caused by a fissure or varix permitting the medium to enter the venous system. COOPER JR (1953) described the rectal tube as a lethal instrument. Similar fatal cases have occurred in Sweden during the last two decades although they have not been published.

Any injury of the rectal wall made by a thermometer or cleansing enema before or at the beginning of the examination may thus produce contrast filling of the

Submitted for publication 2 June 1969

## ZUSAMMENFASSUNG

Ein Gerat zur direkten Punktion der Arteria carotis, das aus einer Modifikation der Stille Infusionskanule besteht, wird beschrieben Die Kanule hat sich in einer einjahrigen Probe zeit gut bewahrt

## RESUMÉ

L auteur decrit l appareillage de perfusion de Stille applique a la ponction directe de l artere carotide Un essai de plus d un an a montre l interet de ce trocart

## REFERENCE

Soila P Introduction of a soft cannula into the carotid artery by direct percutaneous puncture Acta radiol Diagnosis 1 (1963), 451

FROM THE ROENTGEN DEPARTMENT (DIRECTOR OVE MATTSSON), ERSTA SJUKHUS, STOCKHOLM, SWEDEN

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Fig 1 The single opening (arrow) of a conventional enema nozzle is often pressed against the rectal wall during insertion

veins As soon as a sealed communication between the tip and the perforated mucous membrane exists, such a situation may arise At double-contrast examinations air may also be insufflated into the intestinal wall in cases of defects in the wall

The present conventional design of catheter tips with a single outlet favours the effect described — local pressure increase built up by close contact between the opening of the tip and the intestinal wall Thin hard tube-like enema nozzles with sharp edges that may readily damage the mucous membrane are also in use Nozzles with a rounded end and a single outlet, the diameter of a lead pencil, are often employed, these may produce dangerous effect

The main principle of the new catheter is a tip with a multiple opening The risk of occlusion and pressure increase are thus practically eliminated, the risk of



Fig 2 An early model (1955) of a nozzle with a multiple opening

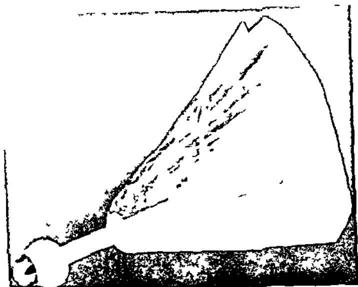


Fig 3 The new disposable enema nozzle with multiple small holes A thin plastic collar protects the hands of the operator and decreases the possibility of spread of bacteria from the rectum

obstruction of all openings by soft tissues must obviously be remote In 1955 the author constructed an enema tip which had a few holes around its pear shaped end and was made of bakelite laminate (Fig 2) It aroused little interest A disposable cheap single-opening nozzle was marketed some years later and has been much used Two accidents that might be referred to the single opening principle have recently occurred in Sweden

The new enema tip is made of polythene The design of the tip as well as the location of the holes are paramount — the safety lies in the distribution of the openings around the periphery of the end, the whole is streamlined to facilitate application and function as well as to eliminate any risk of mechanical injury The nozzle, which is disposable, is shown in Fig 3 A thin plastic collar protects the hands of the operator during its handling To avoid the tip being introduced too far into the rectum a round plate, visible through the plastic collar, is located on the tube part

Safe enema nozzles are essential for every kind of wash out enemas prior to colon examination, or roentgen diagnostic enemas The present instrument appears to constitute an advance

## Acknowledgement

The construction has been developed in cooperation with Bertil Carlsson, Medical Plastic Equipment

## SUMMARY

A new multiple opening tip for a barium enema nozzle is described. It is claimed to be safer than those normally in use.

## ZUSAMMENFASSUNG

Eine neue Kanüle für den Bariumeinlauf mit mehreren Öffnungen wird beschrieben. Sie scheint zuverlässlicher als die bisher benutzten Kanüle zu sein.

## RÉSUMÉ

Description d'une nouvelle canule pour lavement baryté dont l'extrémité comporte plusieurs orifices. Son emploi paraît moins dangereux que celui des canules utilisées habituellement.

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